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ANTARCTIC ECOSYSTEM RESEARCH GROUP

La Jolla, California

Program Plan for AMLR Completed

A program plan for the Antarctic Marine Living Resources (AMLR) program was completed by Rennie Holt in January. The U.S. AMLR program of directed research is explicitly defined by this program plan.

In summary, the program plan states:

The U.S. AMLR program is a national program providing information needed for U.S. policy relating to the conservation and management of marine living resources in the ocean areas surrounding Antarctica. The program is in support of the U.S. participation in the Commission and Scientific Committee of the Convention of the Conservation of Antarctic Marine Living Resources (CCAMLR), which established a system for managing the living resources of the Antarctic ecosystem through international cooperation.

The Antarctic Marine Living Resources Convention Act, P.L. 98-623, was signed into law in 1984, implementing the CCAMLR for the United States. Congress found that directed and basic research programs concerning the marine living resources of Antarctica are essential to achieving the U.S. goal of effective implementation of the CCAMLR. Section 312 of the Act states that: "1) The Director of the National Science Foundation (NSF), in consultation with the Secretary of State, shall continue to support basic research investigations of the Antarctic marine ecosystem as part of the United States Antarctic Program;" and "2) The Secretary of Commerce, in consultation with the Director of the NSF, the Secretary of State and the heads of other appropriate Federal agencies, shall design and conduct a program of directed scientific research [emphasis added] coordinated with the United States Antarctic Program."

The U.S. AMLR program is designed to complement the U.S. Antarctic program (USAP) of basic research managed by the NSF, with the goal of maximizing the productivity of the overall U.S. science effort in Antarctica through close coordination in planning and cooperative work between the two programs, where appropriate.

The presence of large fishing fleets has already contributed to the over exploitation of Antarctic fish stocks and whale populations. It is estimated that in the 50 years between 1930 and 1980 the populations of blue, fin, sei, humpback whales were reduced to 10% of their former abundance levels. The recovery of depleted whale stocks is dependent, in part, on the continued availability of krill in the rich southern ocean feeding grounds. Several countries are also fishing for krill. Excessive fishing effort in local areas could have an adverse impact on local populations of krill-dependent predators. The AMLR program is designed to provide information on the actual and potential impacts of these fisheries on the recovery of depleted populations in relation to the overall structure and function of the principal components of the Antarctic ecosystem.

In cooperation with other government agencies and the private sector, the National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration (NOAA) has implemented the AMLR program, emphasizing directed research to provide for effective conservation of the marine living resources of the Antarctic ecosystem, the primary goal of the CCAMLR. The AMLR program is intended as a U.S. contribution to joint international research efforts which are being planned and undertaken by the member countries of the CCAMLR, in support of the objectives of the Convention.

Studies in support of AMLR objectives include: 1) assessments of catch, effort, and related biological data to determine and monitor the effects of fishing on both target species and species taken as by-catch during commercial fishing operations; 2) baseline surveys and periodic sampling to detect and monitor natural variation and possible harvest-caused changes in key components of the Antarctic marine ecosystem, including plankton, krill, fish, seals, whales, squid, and seabirds; 3) biological surveys to validate the reliability of catch, effort, and related biological data provided by countries engaged in commercial operations in the Convention Area and to assess the effectiveness of conservation measures enacted or contemplated by the CCAMLR; and 4) planning and implementation of coordinated multinational research programs and experiments to test and develop standard survey techniques, improve knowledge of the structure and dynamics of the Antarctic marine ecosystem, and test hypotheses concerning the direct and indirect effects of different harvest levels and strategies. (J. Rosenberg, FTS 893-7600)

First Leg of AMLR Research Cruise Completed

The first leg of the 1989-90 research cruise of the Antarctic Marine Living Resources (AMLR) program was completed on January 30. The goal of the AMLR field program is to determine critical ecological relationships in the Antarctic pelagic marine ecosystem, specifically among key environmental factors, prey, and predators. The principal objectives of the field effort are to describe 1) the physical structure of the mixed layer, 2) the distribution of primary productivity, 3) the distribution of krill, and 4) the foraging patterns, reproductive success, and condition of krill predators within a 100 square mile expanse around Elephant Island, Antarctica.

Most of the studies of the AMLR field effort are conducted aboard the NOAA Ship *Surveyor*. In addition, a permanent field camp on Seal Island, a small island off the coast of Elephant Island, has been established to assist in conducting the foraging and reproductive studies.

The Seal Island field camp is manned by five scientists from the National Marine Mammal Laboratory: John Bengtson, Peter Boveng, Steve Osmek, Mike Goebel, and Don Croll. In order to be present at the onset of the reproductive season of penguins and seals, the field team was transported to Seal Island on December 14 with the help of the tourist ship, the *Society Explorer*. The team members were pleased to find that the camp itself had survived the Antarctic winter unscathed, although a NWS remote weather station installed in a previous season had sustained some damage. Scientific activities started almost immediately, and time-depth recorders (TDRs) and radio transmitters were attached to female fur seals in conjunction with the planned foraging studies. In addition, a penguin census and a study of penguin breeding success and chronology were begun. By December 30, fur seal pupping had ended and monitoring of female feeding began.

The *Surveyor* left Punta Arenas, Chile on January 1 with Roger Hewitt of the Southwest Fisheries Center as cruise leader for the first of two legs. Fortunately, the crossing of the infamous Drake Passage went smoothly, and bathymetric data were collected using the ship's Seabeam system. Lawrence Lawver of the University of Texas conducted the Seabeam studies. The first mission of the *Surveyor* was to resupply the Seal Island field camp. This task was completed with the transferring of 11,000 pounds of cargo to the camp on January 5. On January 6, the first of four replicate 7-day surveys was begun aboard the *Surveyor*. Each survey included hydroacoustic studies of krill, direct krill sampling with bongo net tows, CTD/rosette casts, and phytoplankton/primary production studies. Michael Macaulay of the University of Washington led up hydroacoustic studies; Valerie Loeb, Moss Landing Marine Laboratories and John Wormuth, Texas A & M University conducted the direct krill sampling; Anthony Amos of the University of Texas was in charge of the CTD/rosette studies; and Osmund Holm-Hansen, Scripps Institution of Oceanography, conducted the phytoplankton/primary production studies. The CTD and bongo net deployments were facilitated this year by a new midship J-frame installed on the *Surveyor* in November, 1989. The MOCNESS net was deployed once during the first survey when krill concentrations indicated that a stratified sampling was warranted. The first survey was completed on January 11.

Back on Seal Island, the scientists continued the monitoring of fur seal pups and penguin chick growth rates. In the early part of January they first observed the predation of fur seal pups and penguins by leopard seals. In addition, radio transmitters and TDRs were deployed on adult chinstrap and macaroni penguins. On January 12, Boveng and Bengtson joined the *Surveyor* to take part in the fur seal and penguin tracking studies. The tracking studies went very well. On separate trips three fur seals, three chinstrap penguins and three macaroni penguins were followed to their respective foraging areas; a direct krill sample was taken at each area with a bongo net tow. Hydroacoustic data on krill distribution were also collected during the tracking studies. Seabeam data describing sea floor bathymetry were collected continuously during all operations; bathymetric data collected by the Seabeam system are significantly improved from last year's data due to better navigation data input to the record. Bengtson and Boveng returned to Seal Island on January 20 after completing the tracking studies.

During mid-January, opportunistic marine mammal observations were made; 3 sperm whales, 17 finback whales, 54 southern bottlenose whales, and 1 killer whale were sighted. Later in January, humpback whales were observed near Clarence Island. Scott Baker of the National Cancer Institute and Gregory Stone of the NOAA National Undersea Research program were involved in obtaining tissue samples from the mysticete whales.

The second 7-day survey around Elephant Island was completed on January 27. The hydroacoustic survey for krill used a V-fin depressor deployed from the stern of the ship. As usual, the survey was interrupted with scheduled stops for CTD casts and bongo net tows. CTD casts on this second survey were to depths of 750 meters or 90 percent of the bottom depth. The V-fin depressor was damaged on this survey; however, the scientists and crew were able to repair it to working order. The MOCNESS net was successfully deployed five times in order to obtain plankton samples from discrete layers in the water column. Tows were done in two areas where significant abundances of krill were sensed using the hydroacoustic equipment. Another tow was conducted north of Elephant Island just prior to making the transit across the Drake Passage to Punta Arenas for a mid-cruise port call.

In late January, a new ATS-3 satellite communication system was set up on Seal Island that allows for patches into U.S. telephone lines for business calls.

The scientists continued to collect chinstrap and macaroni penguin growth rate data. High seas from a severe storm caused the deaths of approximately 35 of 120 chinstrap penguin chicks that were located in a study plot in a north cove of the island. Two-year old, non-breeding chinstrap penguins, which were banded at Seal Island as chicks, were observed throughout the month, and towards the end of the month one-year old chinstrap penguins arrived on the island. Predation of fur seal pups and penguins by leopard seals continued to be significant. Of the approximately 300 fur seal pups observed, slightly less than half were still alive at the end of January.

In early February, the Seal Island scientists recovered many of the TDRs deployed on the seals and penguins. The records of the TDRs indicated that most fur seal and chinstrap penguin dives are between 50-75 meters, with some dives as deep as 150 meters. Stomach pumping of chinstrap penguins revealed a diet of mostly krill; there seemed to be less fish and squid in adults' stomach contents in comparison to last year's data. Studies of fur seal feces indicated a diet of mostly krill supplemented by fish. The scientists began tagging fur seal pups and banded a total of 2,000 chinstrap penguins chicks.

The *Surveyor* mid-cruise port call in Punta Arenas allowed for the exchange of scientific personnel. Rennie Holt and Izadore Barrett joined the ship as cruise leaders. Roger Hewitt returned to San Diego for a brief stop before heading to Cape Town, South Africa to board the R/V *Africana* to observe South African Antarctic research program. The *Surveyor* headed back across the Drake Passage to begin Leg II of the cruise on February 4. (J. Rosenberg, FTS 893-7600)

COASTAL FISHERIES RESOURCES DIVISION

La Jolla, California

SURVEY SYSTEMS DEVELOPMENT AND EVALUATION

Pacific Sardine Recovery Studied

If the Pacific sardine continues to recover it will require some specific management decisions regarding the harvest of sardines in the California Current region. Methods of estimating biomass range from 'high-tech' to labor intensive and either extreme can cost a significant proportion of the value of the catch. Two papers, one accepted by the Canadian Journal of Fisheries and Aquatic Sciences and one submitted (but not yet accepted) to the CalCOFI Reports, begin the assembly of facts with which to make decisions on the method of monitoring the Pacific sardine stock.

One curious fact about the Pacific sardine is that the number of eggs taken at quantitative net tow stations within the spawning range bears no relationship to the spawning biomass of the stock. It is not until the area encompassed by the spawning is determined, from presence and absence data, that the time series of biomass and egg survey data agree. The annual mean number of sardine eggs per positive tow has ranged only 3-fold since 1930 while the spawning biomass has ranged 200-fold during the same period. One can see from Figure 1 the frequency distribution of eggs changes relatively little among years and samplers. The numbers per positive sample are dominated by the small percentage of very large egg samples. The CalCOFI paper reviews the apparent spawning biomass of Pacific sardine off California from 1940 to 1989.

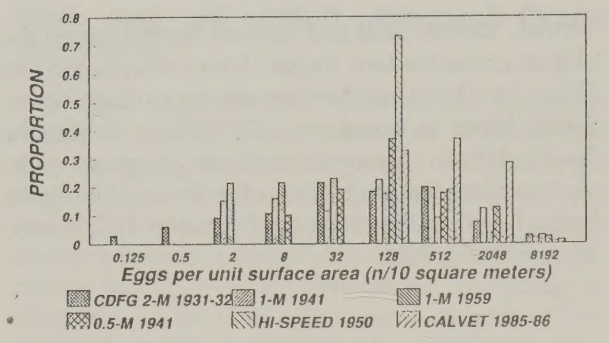

Figure 1. The proportion of samples at each egg number per unit area category for Pacific sardine eggs taken in various years with various quantitative samplers. Note that low concentrations of eggs are below the threshold of certain samplers. The samplers used range from 2 meters diameter (2-M) to a high-speed sampler with an opening of about 2 cm. Current sampler diameters are 0.40-M (Bongo) and 0.25-M (CalVET). The Bongo net has only been successful at capturing sardine eggs a few times since its inception in 1978 and no frequency distribution has yet been established for this net.

A management method which requires only presence-absence data per 0.05 m^2 surface area is studied in detail in a paper by Marc Mangel, Professor at UC Davis, and Paul Smith. In this approach, the probability that the spawning biomass is over or under a predetermined figure is evaluated for Pacific sardine. This will be useful for setting quotas in some cases and determining research procedures in other cases. The paper also explores the conditions in which the presence-absence method is not the preferred method. The main value of the presence-absence method is that the laboratory time spent on the sample is minimized when the biomass of the fish stock is very low. The information in Figure 2 was provided by Patricia Wolf of the California Department of Fish and Game and it illustrates the conversion of presence-absence to spawning area and the time-series of the apparent recovery of the local Pacific sardine stock. We believe that in the last decade this stock has recovered from 1/2000 where it was in 1979 to 1/200 of the Pacific sardine biomass in the early 1930's, where it is now (1989). (P. Smith, FTS 893-7169)

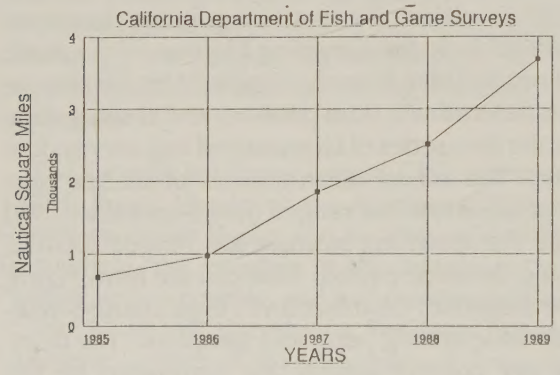

Figure 2. California Department of Fish and Game estimates of the spawning area of the Pacific sardine (P. Wolf).

COMMERCIAL AND RECREATIONAL FISHERIES RESEARCH FOR MANAGEMENT

Progress on the Pacific States Integrated Fisheries Economics Model: PSIFEM

Samuel Herrick, Jr. and Dale Squires, industry economists, and Jack Doll (Summer Faculty Fellow) report continued progress in the development of the Pacific States Integrated Fisheries Economic Model (PSIFEM), a positive quadratic programming model being designed to assess the economic consequences of changing biological and economic conditions within west coast groundfish, pink shrimp, and joint venture whiting fisheries. PSIFEM was initially described in the July-August, 1989 issue of this publication.

The model has been structured to determine the appropriate number of different sized vessels and the extent to which they engage in distinct fishing activities--fishing activities are distinguished by gear type and the manner in which it is deployed (fishing strategy), area, and season--in order to maximize fleet net revenue given expected catch rates, ex-vessel prices and the costs of fishing for the various species landed in each fishing activity. Each size vessel is limited in the number of weeks (amount of effort) it can expend in a particular fishing operation, and there are constraints on the annual catch of each species by area.

The model "builds" vessels in three size categories: small (1-50 ft. length overall (LOA)), medium (51-90 ft. LOA), and large (91+ ft. LOA). The fishing strategies available to each size vessel include: bottom or roller trawl gear fished at depths greater than 201 fathoms, roller trawl gear fished at depths less than 201 fathoms, bottom or sole gear fished at depths less than 201 fathoms, midwater trawl gear fished at all depths, longline gear fished at all depths, fish pots fished at all depths, shrimp trawls, and joint venture whiting gear. Fishing operations take place in four areas: Vancouver, 47°30'N latitude and northward;

Columbia, between 43° and 47°30'N; Eureka, between 40°30' and 43°N; and Monterey, below 40°30'N. Fishing occurs during the winter, spring, summer and fall seasons. This results in 128 distinct fishing operations in which a given size vessel can engage.

The species and species groups harvested in the different fishing activities include: Dover sole, English sole, petrale sole, other flatfish, lingcod, Pacific cod, sablefish, widow rockfish, Pacific ocean perch, thornyhead rockfish, other rockfish, Pacific whiting, halibut, miscellaneous finfish, shrimp, and crab.

The model computes the total revenue per unit effort generated by a vessel engaged in a particular fishing activity based on the vessel's catch per unit effort and the average ex-vessel revenue for each of the species harvested in that activity. Net return per unit effort is the difference between total revenue per unit effort and the corresponding costs associated with generating that unit of effort. Because catch rates, average ex-vessel revenues and cost per unit effort vary by vessel size and fishing activity, likewise will net returns per unit effort. Furthermore, in the positive quadratic programming formulation there are diminishing net returns to effort within a specific vessel size, fishing activity combination. Under these conditions, and the above constraints, the model determines the number of different sized vessels and the amount of effort they generate in each fishing activity to maximize the annual net return from the entire fleet.

To this point, catch per unit effort for each vessel size, fishing activity, and species combination have been calculated using coastwide trawl logbook data for 1986-87. Average ex-vessel revenues have been derived from landings data included in the PACFIN Research Data Base for each species and species group by area, season and vessel size. Costs per unit effort by fishing strategy, area, season and vessel size have been estimated using data contained in the Southwest Fisheries Center's west coast fishing fleet cost-earnings data base. These data together with the total catch and quarterly effort constraints have been formatted according to the GAMS (General Algebraic Modeling System) requirements. Several trial runs have been made using subsets of the data and a simplified specification of the problem to detect flaws in the overall modelling structure. (S. Herrick, FTS 893-7111; D. Squires, FTS 893-7113)

Anchovy Biomass Estimation

Larry Jacobson has made modifications to the Stock Synthesis Model for northern anchovy. These include an option for using Bayesian estimates for recruitment in the most recent years. This modification is intended to provide improved estimates of total anchovy biomass for years (e.g. 1989) in which the availability and total biomass of new recruits is difficult to determine.

The Stock Synthesis Model was modified to obtain standard errors and confidence intervals for parameter and biomass estimates. The correlation matrix for parameter estimates is computed as well. Confidence intervals for biomass estimates will be a routine part of the annual anchovy spawning biomass estimates in the future. The standard errors and confidence intervals will be an important part of the Stock Synthesis Model data requirements/precision study.

Inspection of some preliminary standard errors for parameter estimates indicated that there was an unacceptable level of uncertainty in the model associated with three parameters used to model availability of old anchovy to the Mexican reduction fishery. The problem has been remedied.

Jacobson has moved the Stock Synthesis Model on to the CRAY-YMP supercomputer. The program has been modified to do simulation experiments that will be used to investigate the data required for reliable estimates of anchovy spawning biomass. The number of computations involved in a single simulation experiment will be large and would keep a fast personal computer busy for several months. It is necessary, therefore, to use a supercomputer for the analysis.

Pacific Mackerel Stock Assessment

Patty Wolf and Gary Galovich (CDF&G) and Larry Jacobson have been working to improve the assessment of Pacific mackerel which is done annually by CDF&G. The assessment this year will involve a modified version of the CAGEAN catch-at-age program, commercial catch-at-age data and recreational CPUE data from the Marine Recreational Fishery Statistics Survey. John Witzig (NOAA-Fisheries) has provided detailed CPUE data from the recreational fishing survey that have been used to supplement information available in published reports.

Anchovy Fisheries Management Plan

Cynthia Thomson and Larry Jacobson (SWFC) and Rick Klingbeil (CDF&G) have completed a document that describes a number of options for amending the anchovy Fisheries Management Plan (FMP) to: 1) include a definition of overfishing in compliance with the revised guidelines for the National Standard 1 of the Magnuson Act, and 2) allow small catches by the reduction fishery when the spawning biomass is below the current cutoff of 300,000 metric tons (t).

Three options for amending the reduction fishery quota formula are presented and discussed in the paper. The first option is the 'Status Quo' Option which involves no changes to the current formula. The second option is the 'Unconditional' Option that allows harvest of 7,000 t by the reduction fishery when the spawning biomass is below 300,000 t. The third option is the 'Conditional' option that allows harvest of 7,000 t by the reduction fishery whenever the total biomass is above 375,000 t and the spawning biomass is below 300,000 t.

Two alternatives for the definition of overfishing are considered in the paper. The first is the 'No-Lower-Cutoff' Option that does not impose additional restrictions on harvest when the spawning biomass is low. The second option is the 'Lower Cutoff Option' that eliminates all harvest (including harvests by the live-bait fishery) when the spawning biomass falls below 50,000 t.

Each of the alternatives was analyzed in terms of biological and economic effects; implementation, monitoring and enforcement costs; and compliance and record-keeping requirements imposed on the fishing industry. The major results are as follows:

1) Economic factors tend to protect the stock from overfishing by the reduction fleet when biomass is low.

2) Non-reduction fishing (e.g. for pet food, bait, etc.) is potentially profitable even at low levels of abundance. However, the modest quantities harvested for non-reduction are not likely to have an adverse effect on anchovy abundance, or on the breeding success of California brown pelicans, which prey on anchovy.

3) The Lower Cutoff Option for overfishing could have an adverse impact on the non-reduction fleet and on the recreational fishery in low biomass years. Anchovy are the major source of bait for the recreational fishery, the next best substitute being sardines. The sardine population, however, collapsed in the early 1950's, and the timetable for its recovery is highly uncertain at this time.

4) If adopted, the Lower Cutoff Option for overfishing would require specification of an allowance for the incidental take of anchovy with other bait species. Monitoring of incidental take would require sampling of highly motile catches of mixed species in baitwells and bait receivers, which is likely to cause some injury and mortality to the fish.

5) Implementation costs and compliance and record-keeping requirements are the same for all options. The Lower Cutoff Option imposes a requirement to monitor live bait catches at low levels of anchovy abundance. Monitoring and enforcement costs are otherwise the same for all options.

The Pacific Fisheries Management Council is expected to approve the document and release it for public comment at its meeting in Seattle on March 5-9.

Larry Jacobson and Cynthia Thomson have completed an Administrative Report (LJ-89-26) that documents the analyses that were undertaken in connection with the proposed amendments to the anchovy FMP. (L. Jacobson, FTS 893-7117; C. Thomson FTS 893-7116)

FISHERY-MARINE MAMMAL INTERACTIONS DIVISION

La Jolla, California

BIOLOGY ASSESSMENT PROGRAM

Impacts of Changes in Dolphin Data Gathering Requirements are Examined

Beginning in 1987, the instructions for the collection of life history data by tuna vessel observers were revised. Life history data, including data on species, sex, total body length and reproductive condition of females, are collected from individual dolphins. Both the National Marine Fisheries Service and the Inter-American Tropical Tuna Commission place biological technicians as observers on tuna purse-seine vessels in the eastern tropical Pacific to record the number and species of dolphins killed incidental to the fishery. Prior to 1987, life

history data were collected from all sets. Subsequently, the instructions were amended to request that life history data be collected only if the total observed kill for a set exceeded six animals.

The change in criteria for collection of life history specimens was designed to correct for an observed collection bias in the sampling of female specimens. The collection of specimens from sets in which the kill was small, six or fewer animals, appears to include a preponderance of sexually mature females. Priscilla Akin and Susan Chivers, fishery biologists, are analyzing the life history data collected before and after this change to determine whether the estimation of reproductive parameters has been affected.

Reproductive data for all dolphin stocks with sufficient data available will be analyzed to determine the effect of stratifying the data by the number of animals killed in a set. The data will be analyzed as the percent of females that are mature and the percent of mature females that are pregnant, lactating and resting. Preliminary results for the northern offshore stock of spotted dolphins show significantly fewer sexually mature females in sets with more than six dolphins killed, as expected, but no statistical difference in the representation of females by reproductive state (i.e., pregnant, lactating and resting). The representation of mature females in the life history sample before and after the 1987 change in observer instructions is unchanged in sets with more than six dolphins killed. These results suggest that this change in the criteria for the collection of life history data by observers has not introduced a bias. Analyses are proposed to further examine this question, including whether representation of juveniles and the length frequency of dolphins sampled has changed. (P. Akin, FTS 893-7090)

Research Plan Integrates Division Studies of Population Regulation in Eastern Tropical Pacific Dolphins

Staff members of the Fishery-Marine Mammal Interactions Division (FMMID) have just completed a document describing research for biological studies within the FMMID and how that research is to be integrated with ongoing surveys of trends in population abundance of dolphins in the eastern tropical Pacific (ETP) as well as environmental studies of the region.

National Marine Fisheries Service (NMFS) and Inter-American Tropical Tuna Commission (IATTC) tuna purse-seine vessel observer programs were established, in part, to collect data to make estimates of population size, mortality, and reproductive rates for assessing the impact of the kill by the international purse-seine fleet. The 1984 re-authorization of the Marine Mammal Protection Act (MMPA) relaxed the requirement to determine degree of depletion relative to the optimal sustainable population, and replaced it with an alternate approach for determining status of stocks of ETP dolphin. Rather than estimating absolute abundance, trends in the relative population size will be used to assess status of stocks. This, along with information about carrying capacity (k) and population condition provides the necessary data to ascertain the influence, if any, of the fishing fleet on the stocks.

Information about population abundance and condition, as well as carrying capacity, should interact in a predictable manner. A matrix of theoretical interactions of a population demonstrating density-dependent responses while being harvested is described in the document. For instance, with the assumption of a stable carrying capacity, trends in population condition could be used to track trends in relative population abundance. Simultaneously determining trends in both population condition (K-indices) and size (P-indices) should allow prediction of changes in carrying capacity (k). Simultaneously examining trends in all three allows conclusions to be drawn regarding the effects of harvest.

P-indices are those related to changes in the absolute number of animals. Currently, the Southwest Fisheries Center is conducting a 6-year encounter rate survey of the ETP using two research vessels for 120 days each. Measures of relative population size form line-transect analyses of encounter rates of both research (and tuna vessels) in the ETP are clearly P-indices.

As part of the 6-year surveys of the ETP, extensive environmental measurements are being made. These studies, in part, are designed to provide information of trends in and influences on k of changes in the ETP environment. For example, trends in the average surface chlorophyll level can be used to infer trends in primary production in the study area.

K-indices are indices that relate the average condition of an animal in a population at the current density to the average condition of animals at equilibrium density. For instance, a negative trend in a K-index means that the average condition of an animal in the population is worsening. The NMFS and IATTC have maintained programs to collect

biological data on ETP dolphin species for about 20 years. A variety of biological parameters that theoretically reflect the condition of animals in the populations are thus K-indices.

Life history parameters (K-indices) that respond to changes in density have yet to be identified for ETP dolphins. Simulation modeling will be employed to predict temporal trends in a variety of life history parameters and to investigate the effects of collection bias and harvest. The role of stress will also be investigated as it may be a factor influencing the ability of depleted populations to make density-dependent responses.

If, after the 6-year survey period, trends in the identified K-indices and P-indices are consistent with what we know about the ETP environment (i.e., k), confidence in any recommendations regarding status of stocks and harvest stemming from the research described here will be materially enhanced. The report is available as an Administrative Report LJ-90-03. (S. Chivers, FTS 893-7093)

FISHERY DEPENDENT ASSESSMENT PROGRAM

Pelagic Distribution of Sea Turtles in the Eastern Tropical Pacific is Described

Biological Technician Robert Pitman attended the Tenth Annual Workshop on Sea Turtle Conservation and Biology at Hilton Head, South Carolina, February 20-24, 1990, and presented a paper, "Pelagic distribution and biology of sea turtles in the eastern tropical Pacific." The report summarized sightings data accumulated by Pitman during 24 research vessel cruises in the eastern Pacific over the last 15 years, and included sightings data collected by SWFC tuna vessel observers in 1975. The survey area included about one-half of the tropical Pacific Ocean from Hawaii to the coast of the Americas (Figure 1).

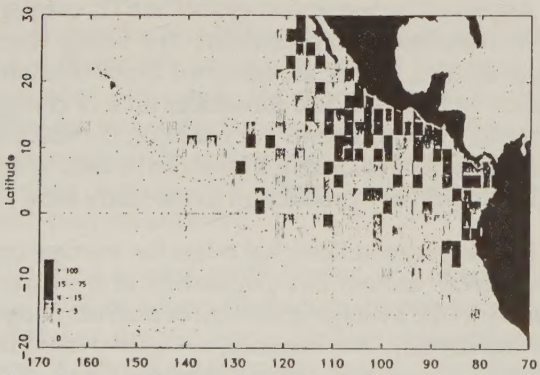

Figure 1. Sightings of sea turtles in the eastern tropical Pacific.

A total of 2,742 sightings of five species of sea turtles was recorded. Olive ridley (*Lepidochelys olivacea*) was by far the most abundant and widespread species throughout tropical waters south of Baja California, while the loggerhead (*Caretta caretta*) was the only hardshell species encountered in the cooler waters off Baja. The provenance of the large population of juvenile loggerheads off Baja is unknown since this species is not known to breed in the eastern Pacific; presumably they are migrants from western Pacific stocks. This accords well with a recently postulated developmental migration scheme suggested for loggerheads in the northern Atlantic whereby adults nest in the western ocean, hatchlings swim/drift to the eastern Atlantic and grow into subadults, and finally return to the western Atlantic to join the adult population. Leatherbacks (*Dermochelys coriacrea*) (39 sightings) were widespread but uncommon in the eastern Pacific; hawksbill (*Eretmochelys imbricata*) and green (*Chelonia mydas*) turtles were rare stragglers in the pelagic zone.

Significant other findings included regular observations of turtles (mainly olive ridley) mating on the open ocean hundreds of miles from the nearest land; hardshell turtles on the open ocean routinely associated with flotsam, most likely for protection but possibly to feed on associated fauna also; seabirds regularly associated with turtles for roosting and to feed on associated fauna (i.e., schooling fishes).

Starting this year, observers on tuna purse seine vessels will once again be collecting data on turtles that are observed at sea or come aboard during fishing operations. This program will allow the SWFC to monitor fishery interactions with sea turtles in the pelagic waters of the eastern Pacific, as well as substantially augment our meager understanding of turtle ecology on the open ocean. (R. Pitman, FTS 893-7198)

COASTAL MARINE MAMMAL PROGRAM

Detecting Trends in Harbor Porpoise Abundance Using Aerial Surveys

Biologist Karen Forney and Research Analyst Jay Barlow, in conjunction with California Department of Fish and Game Marine Biologist Doyle Hanan, have recently completed a manuscript describing a series of aerial surveys for harbor porpoise, *Phocoena*. The aerial surveys were conducted each autumn, 1986 through 1989.

Harbor porpoise are caught incidentally during halibut fishing with gill nets along the central California coast. To assess the potential impact of this fishery mortality, ship and aerial surveys have been used to estimate porpoise abundance. Forney, Barlow and Hanan were primarily interested in detecting changes in abundance over time. Therefore, the ability of aircraft to cover great distances relatively quickly and inexpensively, made them a logical platform for such surveys. Scientists used a chartered twin-engine aircraft to fly predetermined transect lines which zigzagged up the coast between Point Conception and the mouth of the Russian River. Each year, within the survey period, the transect lines were repeated between three and seven times depending on weather conditions.

The number of porpoise seen per kilometer of survey effort was used as an index of abundance. Non-parametric ANOVA was used to determine which sighting conditions significantly affect porpoise counts. The significance factors are included in an analysis of covariance (ANCOVA) model using year as the covariate. Factors which affected sighting rates were included as variables. No significant changes were seen in the abundance of porpoise over the four survey years. Monte Carlo simulations were performed to determine the power of this model to detect trends in abundance. The authors concluded that the ability to detect trends is poor if traditional levels of statistical significance are used. If a larger alpha-error level is accepted, indications of trends may be suggested. Additional survey years are planned and should improve the power to detect trends (J. Barlow, FTS 893-7178).

HONOLULU LABORATORY

Honolulu, Hawaii

INSULAR RESOURCES INVESTIGATION

Effects of Increasing the Opakapaka Minimum Size Limit Examined

The effects of increasing the minimum commercial size limit of opakapaka, *Pristipomoides filamentosus*, on yield per recruit and spawning stock biomass were recently examined by David A. Somerton, leader of the Insular Stock Assessment Program, and Donald R. Kobayashi, biological technician, using a weight-based simulation model of an idealized population of opakapaka. The impetus of their study was a recent initiation of procedures by the Hawaii Division of Aquatic Resources that may lead to an increase in the present 1-lb size limit to the proposed 3-lb size limit for opakapaka, the most important species supporting the Hawaiian bottomfish fishery.

Three aspects of the change in yield per recruit were considered: 1) the decrease in yield that occurs initially after the imposition of a minimum size limit, 2) the size of the ultimate increase in yield at the new equilibrium, and 3) the time required to reach the new equilibrium. All three aspects were computed at each of two levels of fishing mortality assumed to encompass the true value. The initial decrease in yield, expressed as a percentage of the initial equilibrium yield, ranged from -48% (F = 0.3) to -66% (F = 0.6; Figure 1). The change in equilibrium yield per recruit was -4% (F = 0.3) to 10% (F = 0.6). The time required to reach an annual yield equal to 95% of the new equilibrium value was about 8 years (F = 0.3) to 7 years (F = 0.6). Also computed was the time to break even, that is, the time required for the cumulative yield obtained after the change in minimum size to just equal the cumulative yield that would have been obtained without the change. The break-even point was never reached at F = 0.3, but was reached in about 24 years at F = 0.6, indicating that a fairly substantial period must elapse before the bottomfish fishery would fully realize any potential benefit, in terms of yield, that an increased size limit might allow.

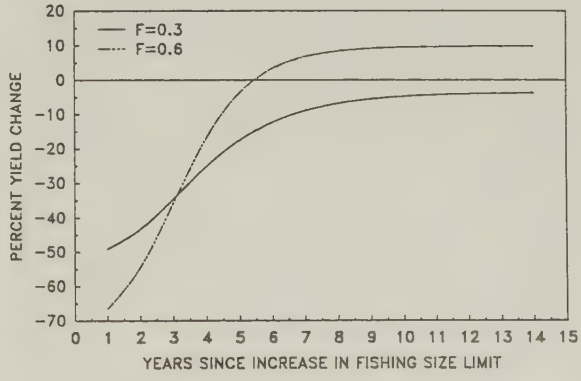

Figure 1. Change in the yield per recruit over time, expressed as the percentage difference from the initial equilibrium yield per recruit.

In addition to increases in yield that might be achieved by increasing the minimum size limit,

potential increases in the biomass of the spawning stock also were examined. The increase in equilibrium spawning stock biomass ranged from about 110% ($F = 0.3$) to about 290% ($F = 0.6$; Figure 2). Although the potential increase in spawning stock is large, any benefits gained from such increases will be in terms of increased recruitment and therefore are difficult to quantify because the relationship between recruitment and spawning biomass is unknown.

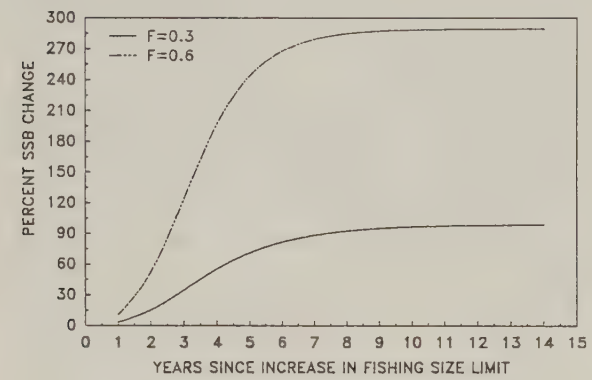

Figure 2. Change in the cumulative yield over time, expressed as the percentage difference from the cumulative yield that would have been obtained without the size limit (SSB = equilibrium spawning stock biomass).

These predicted changes in yield and spawning biomass assume that undersized fish experience no fishing mortality; however, opakapaka occur in deep water, and few undersized fish would likely survive the effects of capture and release. To estimate the effects of such sublegal fishing mortality, yield per recruit and spawning biomass were recomputed by using fishing mortality rates in the sublegal size range equal to one-half those in the legal size range. The new equilibrium yields were -27% ($F = 0.3$) to -34% ($F = 0.6$), relative to the initial equilibrium yield. Thus, the annual yields remained so low that the break-even point would never be reached. The equilibrium values for spawning stock biomass were 47% ($F = 0.3$) to 113% ($F = 0.6$), slightly less that one-half of the increase predicted with no sublegal mortality. This result indicates that even a moderate level of fishing mortality on undersized fish eliminates all potential gain in yield and much of the gain in the spawning stock biomass.

The ability of fishers to avoid catching small fish will clearly determine the efficacy of an increased minimum size limit, but at present, there is no clear idea of how successful they might be. At best, increases in yield would be small and not fully realized for many years. Increases in spawning biomass, however, would be substantial, even with the sublegal mortality that is likely to occur, but it is uncertain whether increases in spawning biomass would eventually result in higher recruitment rates. (D. Somerton (808) 943-1259)

Annual Report on Status of NWHI Lobster Stocks Completed

The fifth annual report on the status of the lobster stocks in the Northwestern Hawaiian Islands (NWHI) was completed in February 1990 by Jeffrey J. Polovina, chief of the Insular Resources Investigation. A system of dynamic Gompertz production models was fit to commercial catch and effort data from three banks and also from the entire NWHI. This model estimated the maximum sustainable yield for the combined stocks of spiny lobster, *Panulirus marginatus*, and slipper lobster, *Scyllarides squammosus*, at about 1.0 million lobsters from an effort of about 1.0 million trap-hauls (Figure 3). The 1989 landings equaled 1.16 million lobsters from 1.07 million trap-hauls.

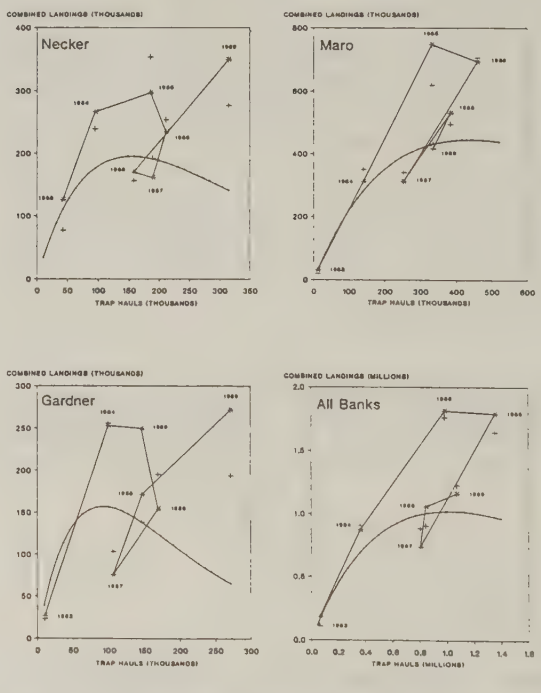

Figure 3. Combined legal landings of slipper and spiny lobsters, estimated landings based on a Gompertz dynamic production model, and equilibrium catch and effort curves for Necker Island, Gardner Pinnacles, Maro Reef, and the entire Northwestern Hawaiian Islands. * = actual landings; + = estimated landings based on the Gompertz dynamic model; and .-.- = estimated equilibrium catch and effort Gompertz curve.

A simple constant recruitment and constant catchability recursive model estimated the monthly catch per unit effort (CPUE) as a function of the previous month's estimated CPUE, and reported fishing effort was fit to the monthly CPUE time series (Figure 4). The CPUE model fit the general change in CPUE over the period 1984-89 well, but there was considerable variation in CPUE within and between years that could not be explained by fishing effort alone and may be due to variable recruitment, catchability, or both (Figure 4).

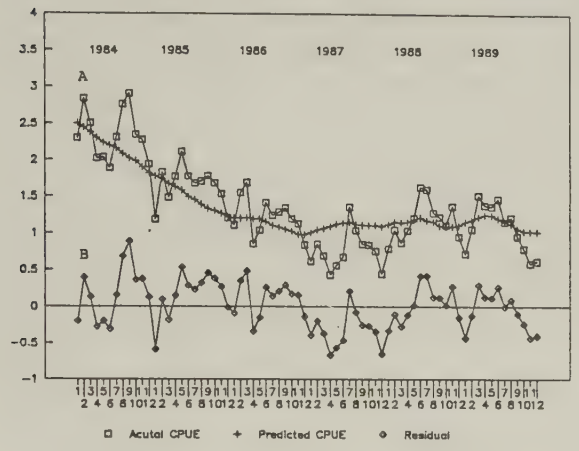

Figure 4. (A) Monthly catch per unit effort (CPUE) for legal slipper and spiny lobsters with predicted CPUE based on constant catchability, recruitment, and natural mortality. (B) Residuals of actual and predicted monthly CPUE.

Estimated fishing mortality was about equal to natural mortality, and the estimated spawning stock biomass per recruit at this level of fishing mortality was 52% of the spawning stock per recruit in the absence of fishing. (J. Polovina (808) 943-1218)

Lessons Learned from 6 Years of Research on Artificial Reefs

"Applications and impacts of artificial habitats in fishery management" was recently completed by Jeffrey J. Polovina, chief of the Insular Resources Investigation, for a book on artificial habitats to be published by Academic Press. The chapter reviews the applications of artificial habitats (i.e., reefs and fish aggregating devices) to 1) artisanal fishing, 2) small-scale commercial fishing, 3) recreational fishing and diving, and 4) mitigation of habitat loss.

The chapter concludes that artificial habitats may function in three ways: 1) redistribute biomass that is being exploited, 2) aggregate unexploited biomass to increase exploitable biomass, and 3) improve survival and increase total biomass. Ecological considerations and estimates of biomass densities at artificial habitats suggest that new production due to artificial habitats will not exceed 0.02-0.5 kg/m^3. Fishery catches from artificial habitats exceeding this range are due to biomass aggregated by the habitats. Reports of fishery catches from artificial habitats are often in the 5-20 kg/m^3 range, indicating that artificial habitats are primarily functioning as aggregating devices. The implication for fishery management is that artificial habitats are most effective when used in a management system that takes advantage of their potential to change the distribution of resources and resource users and to alter gear use practices and the size and species of animals harvested. (J. Polovina (808) 943-1218)

PELAGIC RESOURCES INVESTIGATION

Three Manuscripts Completed

A manuscript entitled "Effects of open and closed system temperature changes on blood oxygen dissociation curves of tuna (*Thunnus albacares*) and skipjack tuna (*Katsuwonus pelamis*)" was completed by Richard W. Brill, fishery biologist with the Honolulu Laboratory, and Peter G. Bushnell, University of British Columbia, and sent for outside review. This manuscript is based on work that is part of a larger project to determine the low ambient oxygen tolerance of tropical tunas. The objective of this project is to provide data for input into computer models capable of predicting movements, abundance, and gear vulnerability of tunas based on oceanographic conditions.

This particular study was undertaken to determine the effects that temperature has on the ability of tuna blood to bind and release oxygen. These data are needed to understand the ability of tunas to withstand low ambient oxygen conditions at various temperatures. Previous efforts in this area have shown tuna hemoglobin solution and whole blood oxygen dissociation curves (ODC's) to be either temperature independent or to have a reversed temperature effect (i.e., O_2 affinity increases with increasing temperature) when subjected to open system (i.e., constant pO_2 and pCO_2; variable O_2 and CO_2 content) temperature changes. This highly unusual behavior has been hypothesized to reflect the necessity of tunas having temperature independent O_2 loading at the gills or to prevent arterial to venous oxygen

transfer as tuna blood is warmed as it is passed through vascular counter-current heat exchangers. Other studies on the effects of closed system (i.e., constant O_2 and CO_2 content; variable pO_2 and pCO_2) temperature changes on tuna blood showed reversed temperature effects on blood from one tuna species (albacore, *Thunnus alalunga*) but normal temperature effects on blood from another species (kawakawa, *Euthynnus affinis*).

In this study, ODC's of blood from yellowfin and skipjack tunas were found to be temperature independent in the open system, but only the latter showed temperature independence when subjected to closed system temperature changes. Blood from both species also showed unusually large Bohr coefficients ($\Delta p_{50}/\Delta pH$). This study clearly showed that blood with a temperature independent ODC, when subjected to closed system temperature changes, is not obligatory in thermoconserving fishes such as tunas.

A second manuscript, "Horizontal and vertical movements of Pacific blue marlin captured and released using sportfishing gear" by Kim N. Holland of the University of Hawaii at Manoa, Brill, and Randall K. C. Chang, fishery biologist with the Honolulu Laboratory, was completed recently and will be submitted as a note to Fishery Bulletin. The manuscript describes the results of tracking marlin carrying ultrasonic depth sensitive transmitters off the Kona coast, Island of Hawaii, over the past two summers. Marlin tracking efforts in Hawaii more than 15 years ago implied that these fish die soon after release, because three of the five marlin with transmitters attached died shortly after release. In contrast, of the six marlin tagged and released in the present study, all survived for as long as they were tracked, and two of the fish survived for at least 48 hours.

The swimming behavior observed in Pacific blue marlin, *Makaira mazara*, contrasts sharply with that observed in tunas. As shown in Figure 5, there is no evidence of cyclic diel movements that would bring the fish back to the starting points. Of the five marlin tracked off the Kona coast, all moved directly offshore immediately after release, and then turned either north or south and continued on a relatively straight course for the duration of the track. In addition, this study clearly shows that marlin occupy much shallower depths than do tunas (Figure 6). Marlin were shown to be creatures of the upper mixed (i.e., uniform temperature) layer. These data have implications for setting commercial longline fishing gear to specifically target the deeper swimming and more commercially valuable bigeye tuna, *Thunnus obesus*, while avoiding marlin, which are more highly prized by the recreational fishing community.

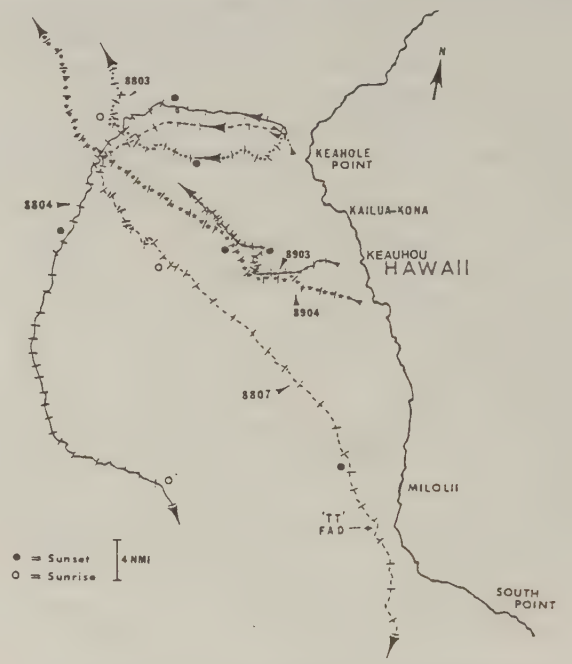

Figure 5. Horizontal movements of five Pacific blue marlin tagged off the Kona coast of Hawaii. The lines perpendicular to the tracks represent hourly positions.

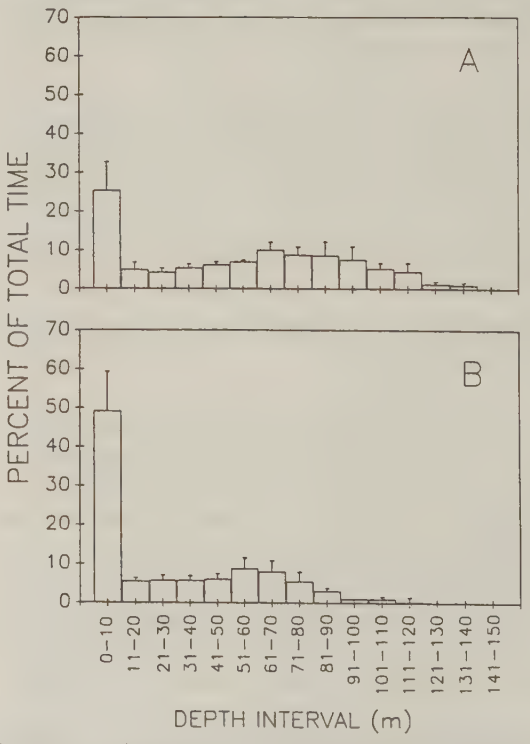

Figure 6. Aggregate depth distribution of all six marlin during daytime (A) and nighttime (B).

A third manuscript, "Metabolic and cardiac scope of high energy demand teleosts--the tunas" by Brill, Bushnell, and David R. Jones, University of British Columbia, was completed recently and sent for outside review. This manuscript is to accompany an invited presentation at the 29th Annual Conference of the Canadian Society of Zoologists, which will be held at Simon Fraser University in May 1990.

Although few data are available, tunas appear to have maximum levels of oxygen uptake far above those of most other fishes. This review attempts to define features of the cardiovascular system of tunas that may account for their extreme performance. Tunas have larger hearts, half the mass of similarly sized mammals, but the ratio of compact to spongy myocardium is only slightly, if at all, higher than in other active teleosts. Myocardial aerobic enzyme activity levels are not significantly elevated. The "resting" cardiac outputs of skipjack and yellowfin tunas are roughly four times those of other active teleosts, such as rainbow trout, *Oncorhynchus mykiss*. Their ventral aortic blood pressures are the highest among fishes (roughly three times those of rainbow trout) and appear to be due to a high resistance to blood flow in the gills, since dorsal aortic blood pressures are not exceptional. Heart rates are high, even in "resting" animals, and stroke volumes are approximately 1 $ml \cdot kg^{-1}$. Blood hemoglobin contents of tunas are also high, essentially identical to those of humans, and twice those seen in other fishes.

This manuscript shows how skipjack and yellowfin tunas should be able to increase the arterial to venous oxygen differences approximately threefold; therefore, the tunas appear to need to increase cardiac output only about twofold, at most, during maximum rates of oxygen uptake. This twofold increase is not very different from that in other teleosts. (R. Brill (808) 943-1234)

Local Fishing Show Plans to Feature the Kewalo Research Facility and Research on Tracking Fish with Transmitters

Fishery Biologists Richard W. Brill and Robert B. Moffitt, Biological Technician Frank A. Parrish, all of the Honolulu Laboratory, and Kim N. Holland of the University of Hawaii at Manoa, met with Mike Sakamoto, the writer, producer, and host of the local fishing show Fishing Tales, in January 1990, to plan the shooting of research activities at the Kewalo Research Facility and also tuna, marlin, and opakapaka tracking aboard the research vessel *Kaahele'ale*. The shooting will be done the first week in April, and the show will be aired in Hawaii several months later. This particular television show is well received locally because it features not only fishing but also scientific research associated with fish. A recent episode included University of Hawaii scientist Yoshitsugi Hokama and his work on ciguatera (fish poisoning).

FISHERIES OCEANOGRAPHY RESEARCH PROGRAM

American Samoa Biologists Trained in Identification of Fish Larvae

Fishery Biologist Bruce C. Mundy worked in Pago Pago with biologists of the American Samoa Department of Marine and Wildlife Resources (DMWR) January 22-26, 1990 to establish a reference collection of identified fish larvae to document the characters used for identification of larvae, and to train DMWR biologists in ichthyoplankton identification. The training in ichthyoplankton identification will assist DMWR biologists in studying plankton samples collected in Pago Pago Harbor in 1988- 89 to determine the seasonal occurrence of larvae in the harbor, the seasonality of fish reproduction, and the effects of pollution on the early life history of fishes and other planktonic organisms.

A reference collection of approximately 210 specimens in 78 lots, representing 48 taxa, was assembled for use by DMWR. Certain features of the species composition of the samples were noteworthy. Larvae of many reef families found in the harbor were absent (e.g., the Acanthuridae, Pomacanthidae, and Chaetodontidae). The most abundant families were the Gobiidae, Blenniidae, Tripterygiidae, Apogonidae, and Pomacentridae; all were small species with parental egg care. This trend is seen in abundance of larvae but not in species diversity; many families with pelagic eggs were represented by only one or two specimens.

Few species important to the fisheries were found. Single specimens of the Sphyraenidae, Mullidae, Kyphosidae, Labridae, Leiognathidae, and Lethrinidae were collected. Several Lutjanidae, Scaridae, and Carangidae were present in more than one sample. The notable exception to the paucity of valuable fishes was the occurrence of larval mullet, Mugilidae, in almost all samples.

Larvae of the mesopelagic families Myctophidae and Gempylidae were found in some samples. These larvae must have been passively advected into the harbor. Their occurrence indicates mixing

of oceanic water with harbor water. Mundy made recommendations on the references necessary to identify fish larvae from Pago Pago Harbor, on the appropriate techniques for sample curation, and on the permanent museum collections where the samples could be stored once they are no longer of use to the DMWR. Recommendations also were made on modifications to the sampling design if future studies of this type are planned, and on the utility of the samples for the original purposes of the DMWR study.

The greatest value of this study is to document the seasonal occurrence of larvae, the species composition in the harbor, and the spawning seasons of fishes in the area. Future ichthyoplankton studies in Pago Pago Harbor would be justified to document changes in the biology of the harbor's fish community. (B. Mundy (808) 943-1212)

MARINE MAMMALS AND ENDANGERED SPECIES PROGRAM

Turtle Fecal Pellets Found on Hawaiian Beach Are Studied

Large numbers of buoyant fecal pellets began washing ashore in July 1989 at Kualoa Beach, Oahu, prompting a 40-day closure of the 1 km stretch of beach by the Hawaii Department of Health, according to George H. Balazs, a zoologist who heads the Honolulu Laboratory's Marine Turtle Research Program. In looking for the source of the pellets and their possible health hazards, State personnel initially suspected that the pellets were from pigs; human origin also was suggested. After a request by the State, however, Balazs identified the pellets as originating from the herbivorous Hawaiian green turtle, *Chelonia mydas*.

The green to brownish pellets (0.5-2 cm diameter; 5 cm long) consisted almost entirely of partially digested benthic algae, mainly *Codium* spp. and *Amansia glomerata*, which are commonly eaten by Hawaiian green turtles. Algae particles were clearly discernible with the naked eye after the pellets were broken open, and ova in the feces were determined to be non-mammalian and most likely from flukes that parasitize green turtles in Hawaii and elsewhere.

Over 300 pellets per day (range, 8-470 pellets per day; 40-day total, 5,500 pellets) were counted and collected for disposal by park maintenance personnel during the extreme periods. However, nearshore water samples analyzed by the Department of Health did not exceed the indicator bacterial limits set by the Environmental Protection Agency for ocean recreational waters (i.e., Colony Forming Units of fecal enterococci per 100 ml of seawater). Since the beach reopened on September 23, after the daily number of pellets declined and the health risks to humans were judged to be minimal, a few dozen pellets have continued to drift ashore each day.

The bacteriological aspects of the feces were measured in a preliminary follow-up study by Roger Fujioka and Carrie Fujioka, both of the University of Hawaii's Water Resources Research Center, in collaboration with Balazs. Fecal coliforms and fecal enterococci from turtle pellets freshly collected at Kualoa were low (Most Probable Number ((MPN) 3-43/g of feces) compared with mammalian and avian feces (MPN 10^6-10^8/g of feces). In addition, turtle pellets held at room temperature (21.5-25.5°C) had no multiplication of fecal coliforms or enterococci. Pellets placed in beakers of seawater for 15 days remained intact, were mostly buoyant, and had no bacterial growth. Breaking the feces into small pieces after 15 days also did not result in the isolation of fecal coliforms or enterococci from the water. Cultures performed for Salmonella by a private hospital and by the Hawaii Department of Agriculture were negative.

For the past 10 years, fecal pellets of green turtles have been known to wash ashore in small numbers on certain beaches in the Hawaiian Islands, and they have been used by scientists to identify food sources exploited by the turtles in certain nearshore foraging pastures. However, pellets had not been previously recorded at Kualoa Beach, even in small numbers, and green turtles are only occasionally sighted off this area. No unusual seasonal weather conditions or notable activity by turtles immediately off Kualoa occurred that might help to explain this acute event.

The most plausible area for the fecal pellets to have originated is Kaneohe Bay, which extends for some 13km immediately to the southeast of Kualoa Beach. A relatively large aggregation of mostly immature green turtles resides in the bay for foraging and resting purposes, but the number of resident turtles is not known to have suddenly increased in 1989. Turtles in this bay have experienced an increase in fibropapillomas, a debilitating and life-threatening tumor of unknown etiology. Furthermore, at least half of the turtles that were sighted during diving surveys or were hand-captured for tagging purposes in Kaneohe Bay now have tumors. Throughout the Hawaiian

Islands in 1989, 49.6% of the 113 green turtles reported stranded had these tumors. (G. Balazs (808) 943-1240)

FISHERY MANAGEMENT RESEARCH PROGRAM

1989 Landings of NWHI Lobster Reported

The combined landings of spiny and slipper lobsters from the NWHI totaled 1.16 million lobsters in 1989, up 10% from 1988, according to data collected from the logbooks of NWHI fishermen. For the second year in a row, spiny lobster landings provided the bulk of the catch (81% by number). The 13 vessels active in 1989 took 33 trips, compared with 9 vessels taking 28 trips in 1988. Total trap-hauls equaled 1.07 million in 1989, compared with 845,000 trap-hauls in the previous year. As a result, the total catch per unit effort (CPUE) of legal-sized lobsters dropped from 1.25 in 1988 to 1.08 in 1989. The annual report for the fishery, including both biological assessment and revenue information, will be completed in April 1990. (S. Pooley (808) 943-1216)

Year-End Auction Activity Reported

During the last 2 weeks of December 1989, the number of longline fishing vessels off-loading at the Honolulu fish auction varied widely, from a low of 1 vessel to a high of 10 vessels, according to data collected by Kurt E. Kawamoto, fishery biologist. As a result, the volume of fish available on the auction floor fluctuated dramatically, occasionally causing substantial differences in prices among retail outlets. The NWHI bottomfish vessels made five trips during December, and only three of them targeted the New Year's market. Prices were not exceptionally high because good weather conditions in the main Hawaiian islands allowed local vessels of all sizes to consistently land fresh catches during the holiday period.

The highest priced tuna was a 151-lb bigeye tuna, which sold for $15.90/lb, while prices for onaga (red snapper, *Etelis coruscans*) peaked at $9.50/lb. Average daily prices generally did not exceed $8.00/lb (round weight) for tuna or $4.00/lb for bottomfish. (S. Pooley (808) 943-1216)

Commercial Fishing Vessel Inventory Prepared

A system for summarizing Honolulu-based, large-scale fishing vessel activities by 3-month periods (quarters) and by fisheries was recently completed by Ray F. Sumida, fishery biologist, and Stacey S. Yoshimoto, operations research analyst. The fisheries include NWHI bottomfish, precious coral, NWHI lobster (i.e., *Panulirus marginatus* and *Scyllarides squammosus*), *Heterocarpus* spp., skipjack tuna, and longline. Data for the system came from the shoreside monitoring activities of the Fishery Management Research Program in Hawaii. Data are summarized below for vessels that actively operated in a fishery in 1988 and 1989:

Fishery	Number of active vessels 1988	1989
NWHI bottomfish	13	6
Coral	1	1
NWHI lobster	9	12
Shrimp	1	3
Skipjack tuna	7	7
Longline	54	77

The summary charts are useful for spotting trends in a particular fishery or shifts in participation between fisheries. (S. Pooley (808) 943-1216)

Software System Developed for Modeling Production and Bioeconomics

A software system that allows for the calculation and prediction of biological and economic values from five surplus production models has been developed by Stacey S. Yoshimoto, operations research analyst. Written in dBASE 4, the system employs the Schaefer, Fox, Schnute, and Threshold models as well as a model developed by Yoshimoto; Raymond P. Clarke, a fishery development specialist with the NMFS Southwest Region Pacific Area Office; and Samuel G. Pooley, industry economist and leader of the Honolulu Laboratory's Fishery Management Research Program.

The system calculates intrinsic growth, catchability, and virgin biomass and employs the user's time series catch and effort data. The user can input cost and revenue parameters which are incorporated into a simple bioeconomic model (Gordon) that determines optimal yield, effort, and biomass values for maximum sustainable yield, maximum economic yield, and open access equilibrium, as well as predicted resource rent. The effects of discounting are demonstrated on optimal levels of resource rent, biomass, and yield. Any of the five models can be used to make predictions by using CPUE data from the previous time period and anticipated effort levels in the predicted time

period. The system was developed for a NWHI lobster bioeconomic study by Clarke, Yoshimoto, and Pooley but has been adapted for use in other types of fisheries. Yoshimoto is documenting the system for easier use, and it will be registered in the software catalogue of the Honolulu Laboratory's Data Management and Technical Services. (S. Yoshimoto (808) 943-1243)

Samples Collected for Northeast Fisheries Science Center

Kurt E. Kawamoto, fishery biologist, acquired and shipped samples of yellowfin tuna, albacore, spiny and slipper lobsters, and macrobrachium prawns for a Northeast Fisheries Science Center (NEFSC) project on the identification of processed seafood products through monoclonal antibodies (MCA's). According to Stephen Mayfield, a NEFSC researcher, mice are "immunized" with water soluble protein extracts from the seafood. Over a period of months, a mouse's immune system builds up antibodies which concentrate in the spleen. The mouse is then sacrificed and its spleen removed. The spleen cells are fused with cancer cells from the mouse to create "immortal" hybridomas which secrete the antigens used in species identification. The NEFSC plans to develop a series of MCA's to differentiate a number of important seafood species, which include the western Pacific samples. (K. Kawamoto (808) 943-1210)

Council Meeting Held

The Western Pacific Regional Fishery Management Council and its Statistical and Scientific Committee (SSC) met in Honolulu the week of December 4, 1989. Two key scientific items were on the agenda: 1) the consideration of the planning team's recommendations for approaches to defining threshold levels of biological overfishing in the bottomfish, lobster, pelagic species, and precious coral fisheries, and 2) the review of research on native Hawaiian fishing practices.

At this meeting, Council members determined that the fishery management plan (FMP) for bottomfish should be amended to include quantitative definitions of biological overfishing and that the lobster FMP is already consistent with the threshold requirements. The pelagic species FMP was considered exempt from the requirement because biological overfishing of Pacific-wide stocks was viewed as impossible within the U.S. exclusive economic zones (EEZ's) of the western Pacific; thus, no action could be taken within the U.S. EEZ's to prevent overfishing. The precious coral FMP will be amended, although quantitative information is unavailable for most coral habitat in the region. These determinations will be sent for approval to the Southwest Region of the National Marine Fisheries Service (NMFS).

Council members also determined that the research on native Hawaiian fishing (which complements previous research on native fishing in American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands) is sufficient for the Council to proceed in identifying which preferences for fishing rights would be appropriate for native peoples under the current FMP's. (S. Pooley (808) 943-1216)

Hawaii Fisheries Data Reporting Meeting Held

A joint meeting was held on 29 November 1989 at the Hawaii Department of Land and Natural Resources (DLNR) on the problem of delinquent commercial catch reports. Kitty Simonds, executive director of the Western Pacific Regional Fishery Management Council, called the meeting, which was attended by representatives of the Hawaii Division of Aquatic Resources, Hawaii Division of Conservation and Resource Enforcement (DOCARE), U.S. Coast Guard, NMFS Southwest Region, NMFS Enforcement, and the Honolulu Laboratory.

The DLNR already had sent certified mail notices of delinquencies to a number of Federal bottomfish permit holders and planned to follow up with notices to all delinquent commercial license holders. If responses are not received within 10 days of return receipt, then the DOCARE plans to visit each permit holder, and those with Federal permits will be turned over to NMFS Enforcement. (S. Pooley (808) 943-1216)

PACIFIC FISHERIES ENVIRONMENTAL GROUP

Monterey, California

Computer Graphics for Evaluation of the Pacific Tuna Fisheries Developed

The highly migratory tunas inhabit vast regions of the Pacific Ocean and they are exploited by different fisheries at different stages in their life cycles. Knowledge of their spatial distribution in relation

to the large scale circulation patterns of the Pacific is a necessary prerequisite to any evaluation of the population dynamics of the various populations or any assessment of the fisheries which harvest them. This knowledge can be achieved by in-depth analysis of the large amount of Japanese and U.S. data available on the Pacific tunas; however, it is difficult to convey this information to those responsible for fisheries management or to the public.

In an attempt to make the mass of information available to a wider audience, Fishery Biologist Richard Parrish has developed a series of computer programs and computer graphics which display the Japanese and U.S. tuna catches, fishing effort, and catch rates. The original emphasis of this work was on the catch at size of albacore tuna in the North Pacific troll, baitboat and longline fisheries. However, multispecies aspects of the various fisheries are also being evaluated.

The Japanese longline fishery catches a wide range of tunas and billfishes; however, the fishery is dominated by catches of yellowfin, bigeye and albacore tunas. In the North Pacific the longline fishery primarily takes yellowfin tuna in the central and western Pacific between the equator and about 15°N; in the region of the Equatorial Counter Current and the North Pacific Equatorial Current (Figure 1). Bigeye tuna catches are also high in the Equatorial Counter Current and North Pacific Equatorial Current regions but they are concentrated further east than the yellowfin tuna catches (Figure 2). Bigeye tuna catches are also high along 30°N, east of Japan and to the northwest of Hawaii. Albacore catches are concentrated between 25-35°N in the region south of the North Pacific Current (Figure 3). Albacore catches are at a minimum in the eastern tropical Pacific and in the California Current Extension.

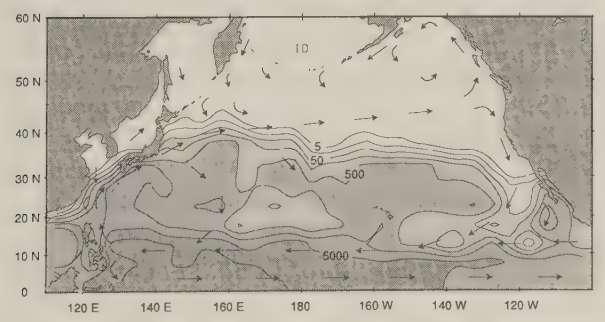

Figure 1. Japanese mean 1962-80 longline catch: 1,050,643 yellowfin tuna (numbers of fish by 5 degree square). Arrows indicate major current systems.

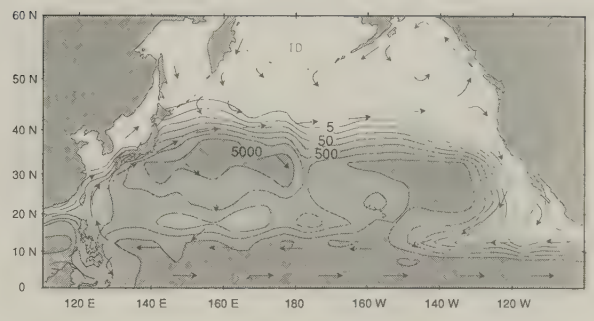

Figure 2. Japanese mean 1962-80 longline catch: 991,071 bigeye tuna (numbers of fish by 5 degree square).

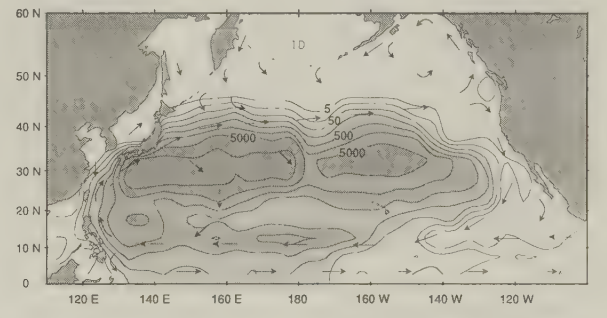

Figure 3. Japanese mean 1962-80 longline catch: 735,496 albacore tuna (numbers of fish by 5 degree square).

Although there is considerable spatial separation of the catches of the three species, when viewed as a whole, it is apparent that the Japanese longline fishery occurs over nearly the entire tropical/subtropical North Pacific, from the equator to about 40°N (Figure 4). Catches are at a maximum from the equator to 15°N and along 30°N in the region south of the North Pacific Current; there is a minimum of catches along 20°N in the region of the central water mass and in the region of the California Current Extension. Japanese longline fishing

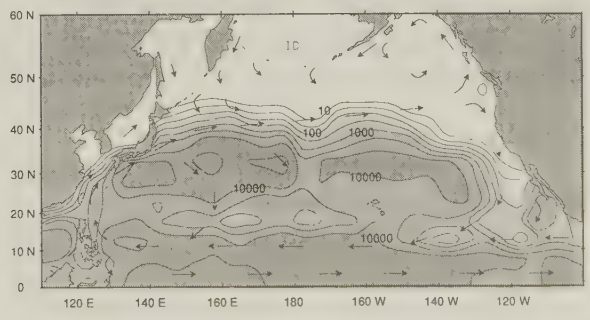

Figure 4. Japanese mean 1962-80 longline catch: 2,777,210 albacore, yellowfin and bigeye tuna (numbers of fish by 5 degree square).

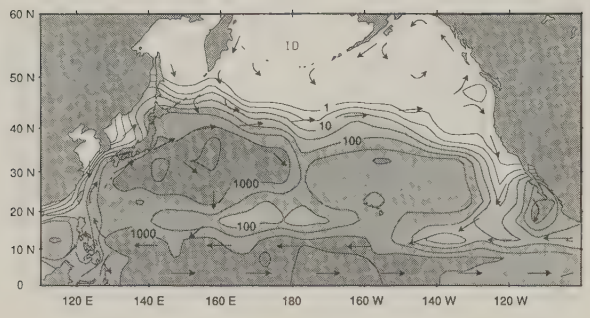

Figure 5. Japanese mean 1962-80 longline effort (1,000 hooks).

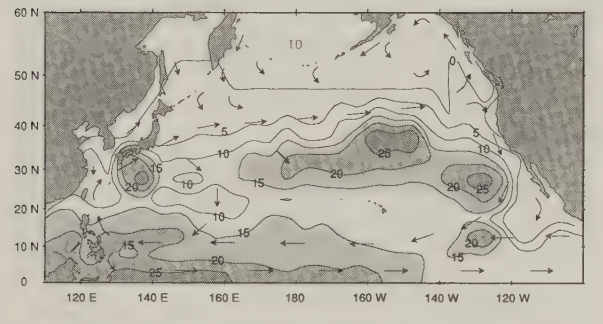

Figure 6. Japanese mean 1962-80 longline catch-per-unit-effort (yellowfin, bigeye and albacore tuna/1,000 hooks by 5 degree square).

effort has a pattern similar to that of the combined catch of the three tuna species; however, in comparison to catches there is a relative lack of effort along 30°N in the region north of Hawaii (Figure 5). Highest rates of the three species occur in the western equatorial region, just south of Japan and in the region to the north and east of Hawaii (Figure 6). (R. Parrish (408) 646-3311)

PELAGIC FISHERIES RESOURCES DIVISION

La Jolla, California

STOCK ASSESSMENT AND IMPACT ANALYSIS PROGRAM

1988 Pacific International Billfish Angler Survey Results

Results of the 1988 Pacific International Angler Survey have been tabulated. The Survey, which was started in 1969, annually conducts a postcard type survey to determine from the participating billfish anglers, the number of days during the year they fished for billfish, and the number of billfish caught by species (striped marlin, blue marlin, black marlin, sailfish, short-billed spearfish, and swordfish). A detailed review of the Survey findings will be given in the 1990 Billfish Newsletter scheduled for distribution in May, 1990.

Information was collected for 1988 in the Pacific, Indo-Pacific and Indian Ocean area for 11,304 angler days which yielded a catch of 6,589 billfish, or 0.58 billfish per angler day. In 1987, 14,847 billfish anglers reported catching 6,625 billfish for a catch rate of 0.44 billfish per angler day. The angler catch rate for 1988 (0.58 billfish per day) is near the value obtained during the first years of the survey (1969-1972, 0.55 billfish per day); however, the 1988 totals include considerably more catches of sailfish, a species that normally has a higher catch rate than the marlins.

For southern California, 2,993 angler days resulted in a catch of 322 striped marlin, equalling a catch rate of 0.11 billfish per day. A striped marlin catch rate of about 0.10 billfish per day is a normal rate for this area. Other areas having substantial catches of striped marlin are found about the southern tip of Baja California Mexico, and off Ecuador. Two thousand forty-four billfish angler days about the tip of Baja California yielded 1,218 striped marlin, for a catch rate of 0.48 billfish per day. This catch rate is down from the 1987 survey result of 0.60 billfish per day. Ecuador normally has the highest striped marlin catch rate of any area sampled. In 1988, 320 billfish angler days were reported in Ecuador with catches of 168 striped marlin for a catch rate of 0.52 billfish per day, down considerably from the 1987 record of 0.70 billfish per day.

A location consistently having high catch rates for blue marlin is the Hawaiian Islands. Mauritius in the Indian Ocean, and Guam, though not reporting many angler days (compared to Hawaii), appear to have good catch rates for blue marlin. For Hawaii, 1,479 billfish angler days were reported, with anglers catching 320 blue marlin for a catch rate of 0.22 fish per day. The catch rate in 1988 was up slightly from that observed in 1987 (0.20 fish per day).

The center of black marlin fishing in the Pacific is off the Queensland area of Australia. This species is also taken by anglers in the Indo-Pacific area (Malaysia, Thailand). For 1988, Australian anglers

(614) reported catching 115 black marlin for a catch rate of 0.19 fish per day. In 1987, and for several years previously (from 1978-1987), the catch rate has remained between 0.47 and 0.58 fish per day. The 1988 survey results indicate a substantial drop in catch rate for black marlin.

Highly productive areas for sailfish are to be found off southwestern Mexico, Central America, eastern Africa and the mouth of the Persian Gulf. In 1988, a record billfish angler catch rate was observed for sailfish off Costa Rica with 334 angler days with anglers catching 886 sailfish. The record average catch rate was 2.65 sailfish per day. Catch rates for sailfish caught off Acapulco, Mexico were 1.05 fish per day; Panama, 1.21 fish per day; Kenya, 1.24 fish per day; and Dubai, United Arab Emirates, 2.00 fish per day.

The 1989 Billfish Angler Survey is now in progress in cooperation with the International Game Fish Association. (J. Squire, Jr., FTS 893-7072)

PELAGIC ECOSYSTEM MODEL DEVELOPMENT PROGRAM

Chartering a Fishing Fleet: Is It a Worthwhile Assessment Strategy?

Pierre Kleiber has ported to a SUN workstation the Tuna Observer Programme Simulator (TOPS), which he and Elizabeth Edwards developed. The TOPS model was created for the purpose of investigating biasing factors in the estimation of dolphin abundance from data collected by observers on tuna vessels. The model simulates a 1200 by 1200 nautical mile patch of pelagic ocean containing up to several thousand dolphin schools that move in response to an underlying environmental quality topography. The model can be adjusted so that dolphins aggregate to a greater or lesser degree on peaks of high environmental quality. The model also contains up to 100 fishing vessels that respond to dolphin encounters in such a way that the vessels tend to aggregate in areas of high dolphin density.

The new version of the model is designed to evaluate a recent proposal to charter the entire U.S. tuna purse-seine fleet for a short period of one or two days to gather data on dolphin abundance. During the charter time each vessel in the fleet would stop normal fishing activities and just count dolphin schools while steaming along a given transect line. It was hoped that this would be a less biased sampling scheme than that of data collected during fishing, when the vessels tend to concentrate on areas of high dolphin density and avoid areas of low density, thereby tending to over-estimate the abundance.

Using the new version of TOPS, Kleiber and Edwards have been simulating several fleet-charter scenarios, varying the degree to which dolphins are aggregated, the number of aggregations, and the terms of the charter. In these runs of the model, 30 fishing vessels are introduced at random positions at time zero. Prior to the charter period, these vessels spend 600 hours conducting normal fishing activities, searching for schools and stopping for 5 hours whenever a school is encountered. At the beginning of the charter period, each vessel is assigned a random direction, and starting from its current position, it steams on this course for 24 hours simply counting dolphin schools. Abundance estimates based on numbers of schools sighted and track miles accumulated by 30 vessels are calculated for each 10 hours of the normal fishing period and for the first and second 12 hours of the charter period.

Figure 1 shows results from six replicate runs of the model with no aggregation of dolphins. These runs were conducted to check that the new version of the model was behaving correctly. The actual dolphin abundance in the model was 2500 schools, and as expected, the estimates, though scattered, tended to agree with that number, both during the fishing period and during the charter period.

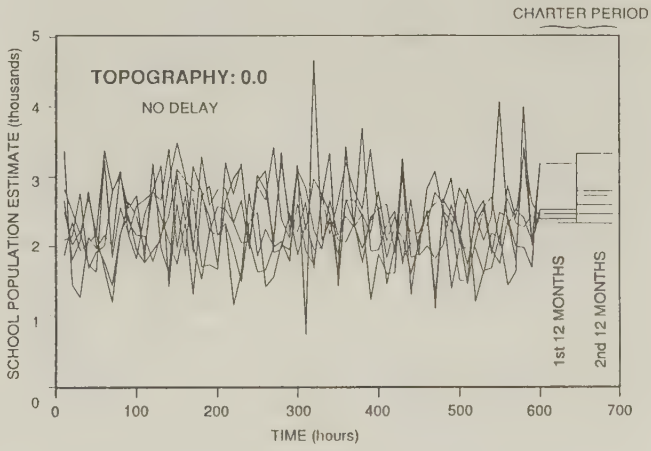

Figure 1. Computer simulation in which dolphin were not aggregated. Charter results for first and second 12-hour periods indicated by horizontal lines on the right.

With dolphins aggregated, the results are very different. When fishing vessels are introduced at random positions, they first tend to underestimate the true dolphin abundance, but as the vessels

aggregate on patches of high density during the normal fishing period, the estimates climb above the true value. The results from the charter period are highly variable, depending on the details of the charter arrangement and on the number and tightness of dolphin aggregations. In all cases tested, the data collected during the first 12 hours of charter greatly over-estimated the dolphin abundance, and the data collected during the second 12 hours yielded much lower estimates, under-estimates in some cases (Figures 2 to 4).

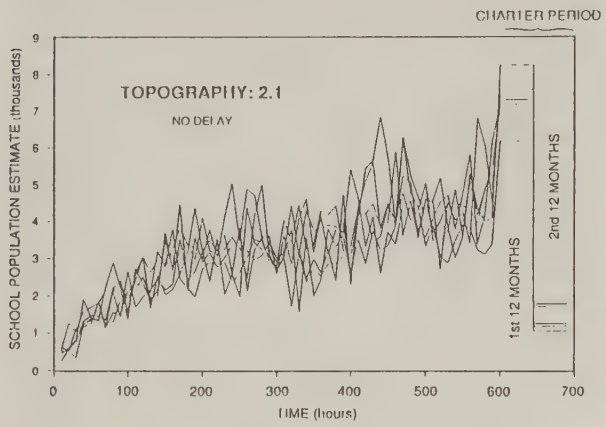

Figure 2. Computer simulation in which there were four loose aggregations of dolphin. Charter results for first and second 12-hour periods indicated by horizontal lines on the right.

The over-estimation results from a disparity in sampling intensity between regions of high and low dolphin density, high density regions being over-sampled and low density regions being under-sampled. Whether in normal fishing mode or charter mode, the sampling intensity depends on the number of track miles accumulated in each type of region, not on the number of vessels. During normal fishing the vessels tend to congregate in high density regions, but they are impeded in their accumulation of track miles by delaying to process each school encountered. Therefore there are fewer track miles sampled per vessel in high density regions than in low density regions. During the charter period, however, the vessels are not delayed by sighting schools. They accumulate track miles at the same rate as vessels in low density regions. As a result, until the vessels steam out of the high density regions, the disparity in sampling intensity can be larger in charter mode than in normal fishing mode.

The shift in the distribution of track miles explains why in some cases, the abundance estimates from the first 12 hours of the charter period are

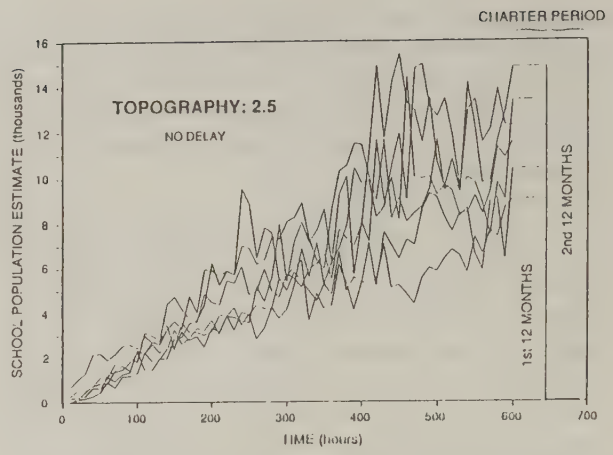

Figure 3. Computer simulation in which there were four tight aggregations of dolphin. Charter results for first and second 12-hour periods indicated by horizontal lines on the right.

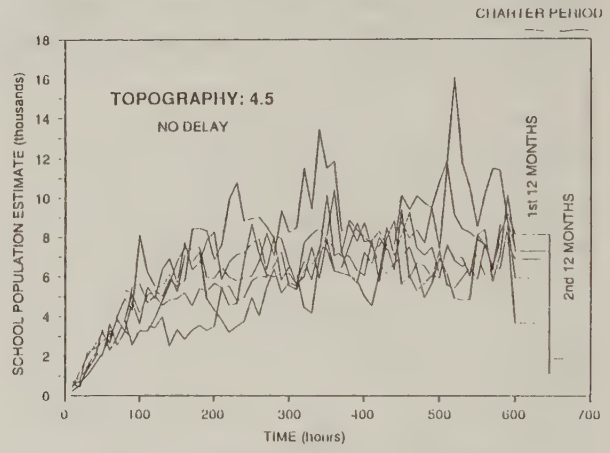

Figure 4. Computer simulation in which there were 16 tight aggregations of dolphin. Charter results for first and second 12 hour periods indicated by horizontal lines on the right.

biased to even higher levels than the normal fishing period estimates (Figure 2). These estimates correspond to a case where the charter period begins at dawn, giving approximately 12 hours of daylight for sighting at the start. On the other hand, if the charter were to start at dusk and the vessels were to steam all night along their tracks, the results would correspond more to the model results from the second 12 hours. In all cases except the no-aggregation case, the estimates from the second 12 hours were considerably lower than from the first. In some cases they were biased in the opposite direction (Figures 2 and 3). This is because in the second 12 hours, most of the vessels have steamed out the patches of high density, and most of their track miles in this time are in regions of low dolphin density.

It would be easy to simulate many more possible scenarios, but it is quite apparent from these preliminary results that the notion of chartering the fleet does not hold much promise in reducing the bias inherent in dolphin abundance estimates from tuna vessel observer data. (P. Kleiber, FTS 893-7076)

TIBURON LABORATORY

La Jolla, California

Book on Fish Population Geography Is Published

Washington Sea Grant has published a book authored by Alec MacCall, Acting Director of the Tiburon Laboratory. The book is titled "Dynamic Geography of Marine Fish Populations" and is based on a series of lectures presented at the University of Washington in the fall of 1986. It is the second volume in a new Washington Sea Grant series called "Books in Recruitment Fishery Oceanography."

This book examines the effects of "density dependent habitat selection" (DDHS) on the distribution and abundance of marine fishes as well as other organisms. The underlying principle of DDHS is that individual fish tend to move toward more favorable habitat when presented with the opportunity, and increased fish population density in that habitat causes a decline in its quality. Formal recognition of DDHS in fishery and population models produces a number of satisfying as well as surprising results:

> Populations are now expected to expand and contract with changes in total abundance, a phenomenon which has been observed widely but previously has not been explained or modeled effectively.
>
> Catch-per-unit effort is expected to decline much more slowly than total abundance.
>
> The shapes of some stock-recruitment curves are changed, with the Ricker model losing much of its declining right limb.

The location of the maximum net productivity level of population growth curves shifts to lower levels of abundance than would be indicated by local dynamics (this may be important for marine mammal management under the MMPA).

Based on analysis of the extensive CalCOFI collections of anchovy larvae, MacCall is able to map the habitat quality as (inferentially) perceived by the northern anchovy off California. The book also examines the possibility of geographically optimal harvesting strategies. For many highly mobile pelagic species, location of harvest is unimportant biologically. However, for species with low mobility and/or for species with extensive larval drift, there may be an opportunity to increase harvestable productivity or to constructively accommodate excess fishing effort by appropriate geographic management policies. (A. MacCall, FTS 556-0565)

Optimal Strategies for Harvest of Klamath River Salmon

In recent years management of chinook salmon in northern California and southern Oregon has been aimed at setting harvest rates that are optimal for the natural stock of chinook salmon spawning in the Klamath River system. One criticism of this management policy has been that the fisheries harvest both natural and hatchery stocks, and the hatchery stocks can support much higher harvest rates than the natural stocks. Therefore, harvest rates should be increased to maximize the landings from the combined stocks.

Robert Kope used stochastic dynamic programming to investigate the question of optimal harvest rates for mixed stock fisheries with markedly different production functions (Figure 1). Solutions generated by this technique were in the form of optimal harvest rates over an array of abundance combinations of the component stocks (Figure 2). If the two stocks had identical stock-recruit functions, the optimal harvest rate isopleths would be

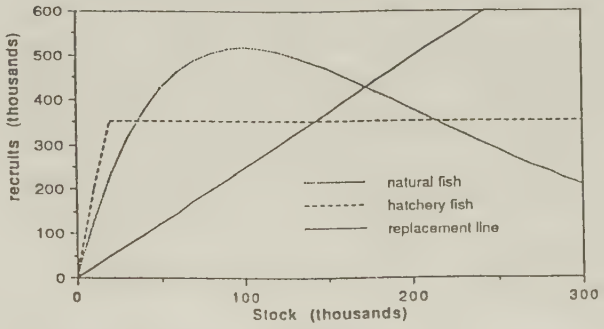

Figure 1. Stock-recruit curves used in the deterministic or equilibrium analyses. Natural stock is governed by a Ricker stock-recruit curve with alpha = 14, beta = 0.00001. Hatchery stock has 20 recruits per spawner up to the hatchery capacity of 17,500 spawners.

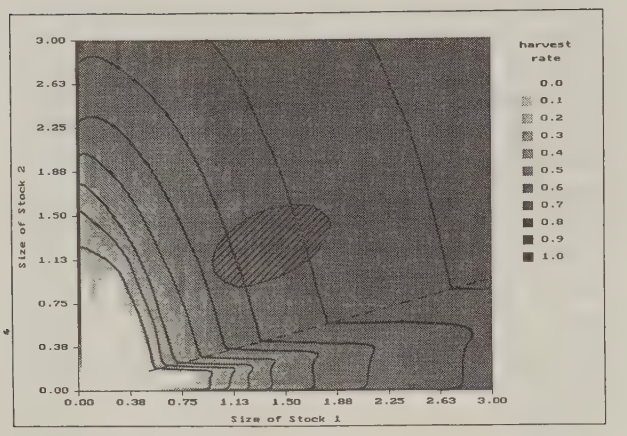

Figure 2. Optimal harvest rate isopleths. Stock 1 (x axis) represents the natural stock with a Ricker stock-recruit relationship. Stock 2 represents a hatchery stock with a constant number of recruits produced by each spawner up to the hatchery capacity. The ridge in the optimal harvest rate contours is indicated by the dashed line, and equilibrium stock sizes under optimal harvest rates would tend to fall in the hatched region.

straight lines connecting identical stock levels on both axes, and optimal harvest policy would be stock-indifferent. However, when the productivities differ, the relative abundances of the component stocks can strongly influence optimal harvest rates. The contours in Figure 2 demonstrate a sharp ridge at abundance combinations where optimal harvest rates are highest for a given level of combined abundance. At these abundance combinations, the optimal harvest rates for the combined stocks are the same as optimal harvest rates for the component stocks individually (i.e., if projected straight down or straight across, optimal harvest rates on the axes are identical to those on the ridge). At abundance combinations that lie off the ridge, optimal harvest policy is dominated by the stock that is relatively weaker. The higher productivity of the hatchery stock dictates that the ratio of hatchery fish to natural fish will remain well above and to the left of the ridge in Figure 2, in the region where the optimal harvest policy depends strongly on the natural stock. (R. Kope, FTS 556-0565)

Automated SWFC Library Catalog to be Developed

The librarians of the Southwest Fisheries Center: Hazel Nishimura, Dave Coleman, Debra Losey and Maureen Woods, are to meet at the Tiburon Laboratory on March 7-8, 1990, to discuss a comprehensive plan for automating the SWFC libraries. They are considering using Library Corporation's The Intelligent Catalog for searching and retrieving books, monographs and serials. The Intelligent Catalog is a CD-Rom version of a library catalog. It is a stand-alone search station (PC, CD ROM reader, and monitor) with monthly updates and service. Pro-Cite is being considered as a software choice to access administrative reports and staff publications.

NOAA Library and Information Services Division in Rockville, MD, has agreed to provide technical support and assist with the task of retrospective conversion of library records. The SWFC librarians look forward to providing the SWFC with a comprehensive, automated catalog. (M. Woods, FTS 556-0565)

GROUNDFISH COMMUNITIES INVESTIGATION

Implications in Unusually Large Number of Juvenile Rockfishes Taken by King Salmon

Based on trawl surveys and underwater counts, investigators at the Tiburon Laboratory have concluded that recruitment by rockfishes has been weak in 1989, and samples of gut contents from king salmon, a major predator on these fishes, generally agree with this. Striking exceptions occurred on 3 days between May 17 and 25, however, when numbers of juveniles taken by salmon were large enough to substantially increase the overall season average. Although otherwise very few juveniles were taken by salmon sampled during the past year, the numbers taken on those 3 days were greater than at any other time during all the years of this study. Even during years of known juvenile rockfish abundance, it has been unusual to examine salmon stomachs that contained more than 10 of them. Particularly exceptional were the salmon sampled on May 17, which contained an average of 17 juveniles, with three containing 61, 61 and 64. In fact, the 59 salmon examined on this one day contained over 30% of the juvenile rockfishes found in stomach contents from all 1,034 salmon sampled during the year.

Aside from demonstrating problems of using multi-day averages in predator diet to estimate relative abundance in the environment, these findings have important implications in the biology of the salmon and/or juvenile rockfishes. Although evidence continues to indicate there were relatively few juvenile rockfishes in the 1989 year-class, it would appear that those present were densely aggregated.

A somewhat unusual species composition may have contributed to these results. Although the shortbelly rockfish (*Sebastes jordani*) has consistently been the major species taken, this year's dominance--86% of the identified juveniles--has been greater than ever before. Second most abundant (5% of the juveniles taken) was the squarespot rockfish (*S. hopkinsi*) which is unusual in that this species has been only an infrequent component of the diet during past years. (P. Adams, FTS 556-0568)

Poor Feeding Conditions during 1989 Affect Physical Condition of Blue Rockfish

The blue rockfish, *Sebastes mystinus*, suffered poor feeding conditions during 1989, as reported in the last Bimonthly Report of Activities from the Tiburon Laboratory's Groundfish Communities Investigation. During the past summer and fall, the seasons when usually this species feeds best, there was a severe shortage of salps and other relatively large gelatinous zooplankters that ordinarily dominate its diet. Presumably this shortage related to unusual oceanographic conditions, including a late transition to the spring upwelling period, and the weakness of that condition when it finally developed.

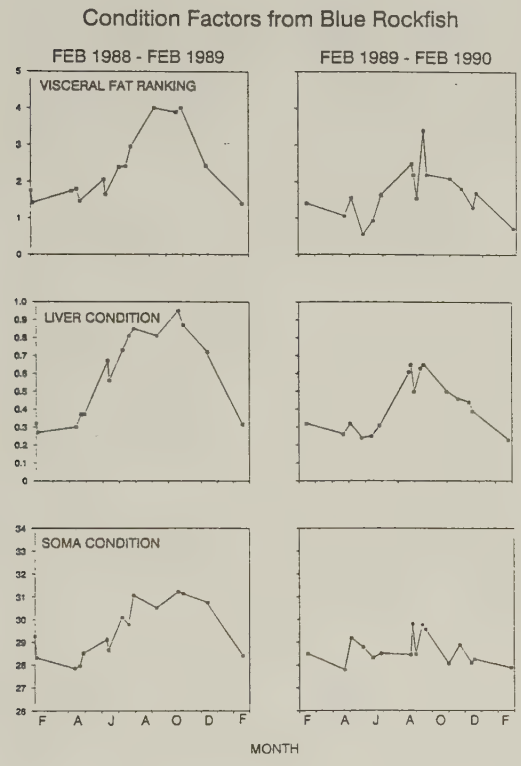
Condition Factors from Blue Rockfish
FEB 1988 - FEB 1989
FEB 1989 - FEB 1990
VISCERAL FAT RANKING
LIVER CONDITION
SOMA CONDITION
F A J A O D F
F A J A O D F
MONTH

Figure 3. Three condition factors from the blue rockfish compared between February 1988 to February 1989 (left), and February 1989 to February 1990. The visceral fat ranking is based on subjective visual estimate of the fat present on a relative scale, 0 to 5. Liver and soma (defined here as body less gonads and visceral) conditions are represented by Fulton's Condition Factor (k = weight/length^3). Data are from 475 adult females, 255 to 346 ($\bar{x}$ = 273) mm SL. Each data point represents 4 to 20, $\bar{x}$ = 14.2, specimens.

Effects of these food shortages became evident in the blue rockfish's physical condition, which Ted Hobson, Tony Chess and Dan Howard have monitored relative to feeding success since November 1988. A comparison of its condition during the past year, compared to the previous year, based on three parameters (Figure 3), clearly indicates less favorable circumstances during 1989. (E. Hobson (415) 556-0568)

GROUNDFISH ANALYSIS INVESTIGATION

Growth in the Early Life-History of Shortbelly

Fishery Biologists Steve Ralston and Tom Laidig, with the assistance of Mathematical Statistician Jim Bence, have analyzed otoliths from larval and juvenile shortbelly rockfish, *Sebastes jordani*, sampled during four cruises completed in 1989. From their detailed examination of daily increments they have described two growth relationships: 1) the association of otolith radius (OR) and standard length (SL) was characterized by four separate linear growth stanzas (Figure 4), and 2) the relationship between SL and age was characterized

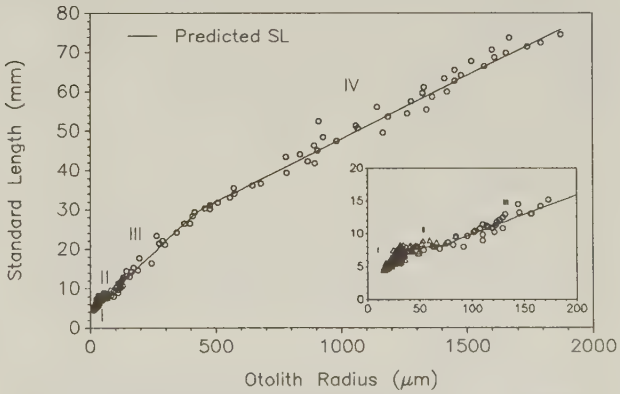

Figure 4. Plot of standard length (SL) and otolith radius (OR) for all aged fish. Inset is an enlarged view of the lower end of the plot. The solid line represents the predicted curve from the multiple linear segmented model. Roman numerals indicate each particular segment.

by a two-stage Gompertz curve (Figure 5). The data were gathered by aging 55 juvenile and 194 larval shortbelly rockfish.

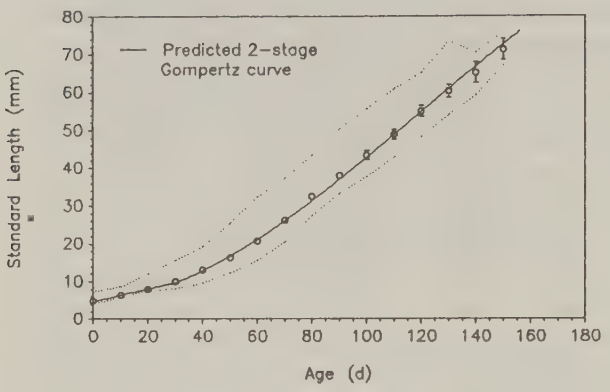

Figure 5. Relationship between back-calculated SL and age for all aged fish. Dotted lines represents the maximum and minimum values at each age. The solid line represents the predicted curve from two-stage Gompertz equation. Circles represent average SL at age. Bars represent two times the standard error.

The four segments of the SL = f(OR) growth model seem closely related to discrete life history events. For example, the inter-section of the first and second segments coincided closely with the specific SL when flexion begins; the join point of the second and third segments corresponded to the completion of flexion. Also, the last juncture occurred at the size of transformation from larva to juvenile. This analysis showed clearly that simplified models may not accurately predict the growth of larval and juvenile fish.

By back-calculating OR and age at each daily increment, and by using the predictive equation of SL on OR, one can estimate SL at back-calculated age for each fish. The equation for this relationship was best modeled by a two-stage Gompertz curve, highlighting again the complexity of growth in the early life history. The intersection of the two curves occurred at a length corresponding to the period of flexion in this species. The use of these two models will allow detailed analyses of growth in relation to environmental conditions.

Validation of the daily periodicity of the otolith rings was also completed. This was accomplished by comparing the progressive change in the mean size of a sequentially sampled cohort against the slope of the relationship of SL and age for the 55 aged juvenile rockfish. The agreement between these two independent methods of determining growth was very good. The validation, however, extends only to shortbelly rockfish; this work is being expanded to other rockfish species in an attempt to prove that the increments observed in their otoliths are truly daily. The results of this study have been summarized in a manuscript that is currently in review. (T. Laidig, FTS 556-0565)

GROUNDFISH PHYSIOLOGICAL ECOLOGY INVESTIGATION

Anomalous Physiological Condition Observed in Northern California Rockfish Population

Because of unusual oceanic conditions during the past few months and in view of the possibility of El Niño conditions occurring this year, we are returning to monthly sampling of adult yellowtail rockfish (*Sebastes flavidus*) over Cordell Bank rather than continuing sampling seasonally. Our intent is to make a better comparison between "normal" years such as occurred during previous years sampled monthly (1985-1989) and an "abnormal" year. We are particularly interested in the relationship of varying oceanic environmental conditions to measures of adult condition and subsequent reproduction and recruitment.

Adult yellowtail rockfish sampled over the last 3 months during the spawning season show clear indications of reduced condition. Fish have virtually no reserve mesenteric fat, reduced fat in livers and calculated liver somatic indices are about approximately one-fourth of those from previous years at this time. Many livers show gross evidence of pathology, and kidney, spleen and liver are heavily infected with the fungus, *Ichthyophonus* sp. In addition, examinations indicate the poor adult condition will be reflected in abnormal gonad development and reduced effective fecundity. Abnormal ovarian development appears to occur in a few females; other females seem to show delayed ovarian maturation, and gonadosomatic indices appear lower than expected.

Subsample analyses and statistical comparisons need to be completed, e.g., proximate analyses of tissues, serum lipids, histological analyses of egg maturation and atresia and fecundity. When analyses are completed, the differences between yellowtail rockfish collected in this anomalous year from those collected in previous years will be described. If results are as hypothesized, the link between environmental conditions, condition of adult fish and reproduction may enable us to better

predict both exceptional and poor year classes in this rockfish species.

Local yellowtail rockfish condition and reproduction may vary from several different populations further north. The center of the yellowtail rockfish distribution is off the Washington coast. Comparisons of fish captured over Cordell Bank off California are being made with trawled samples from Westport, Washington. Observations of yellowtail rockfish captured in February from further north indicate that adult condition is more normal, with average amounts of fat and much better condition. Reproductive development also appears to be more normal, but since analyses are incomplete, we cannot yet be certain of this. (J. Whipple, FTS 556-0569)

Progress in Rockfish Feeding and Nutritional Physiology

The type and quality of food obtained by yellowtail rockfish may vary annually and may relate to condition. To investigate this further, Jeannette Whipple met with Tony Chess of Ted Hobson's Groundfish Communities Investigation to discuss methods of stomach content analysis of adult yellowtail rockfish. A similar procedure and the same species codings used by the Groundfish Communities Investigation will be used. Some additional information, including weight of stomach contents, will be added. Eventually, work on the energy content and availability of the food to the rockfish may be initiated. In order of abundance, the major groups of food species observed so far are euphausids, salps, and myctophids.

A literature search on serum enzymes occurring in fish was completed, and results obtained from measurement of several serum enzymes are being summarized. In human serum, high concentrations of certain serum enzymes are good indicators of organ dysfunction, e.g., of the liver. Interpretation of our results for yellowtail rockfish is incomplete, since little is known of the significance of unusually high or low concentrations of these enzymes in fish. Data for the distribution of enzymes in yellowtail rockfish are being examined in order to determine the distribution and reference range for this species. Outliers are being selected and examined using box plots and other graphical analysis techniques to determine how the condition and reproduction of fish relates to high or low concentrations of the following serum enzymes: alkaline phosphatase (AP), gamma-glutamyl transpeptidase (GGT), glutamate oxaloacetate transaminase (GOT), glutamate pyruvate transaminase (GPT) and lactate dehydrogenase (LDH).

For example, we found that concentrations of AP in yellowtail rockfish show a strong relationship to the reproductive cycle, being significantly lower during the spawning season (December through March). An example of variation in serum alkaline phosphatase within females and between different times in the reproductive cycle is shown in the box plot of Figure 6. The plot shows fish which are

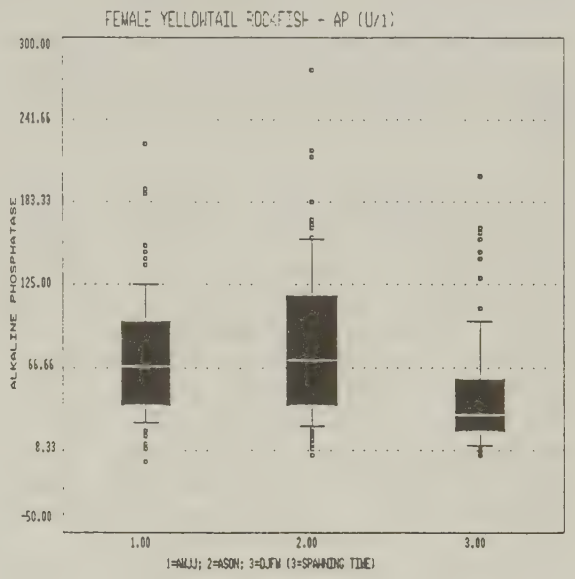

Figure 6. Box plots showing distribution of concentrations of alkaline phosphatase (U/l) in serum of yellowtail rockfish (*Sebastes flavidus*) during three different phases of the reproductive cycle. Single data points or outliers are below 10th percentile and above 90th percentile. Whiskers extend from 25th percentile to 10th percentile and 75th percentile to 90th percentile. Median is line across box and represents the 50th percentile. Box includes 25th to 75th percentile. Phases of reproductive cycle are: 1 - AMJJ = April, May, June, July, 2 - ASON = August, September, October, November, and 3 - DJFM = December, January, February, March - spawning season

outliers (in lower or upper 10% of distribution). Fish falling between 10% and 90% could be defined as being in the normal reference range (approximately 16-135 U/l). The outliers could be diseased fish, although as in most data of this type, false positives and negatives are possible. The median is the line across the black bar, and the position shows that the distribution of values is asymmetrical during the spawning season. The plot also shows the significantly lower concentrations of AP occurring during the spawning season (P.001; analysis of covariance, removing effect of age). (J. Whipple, FTS 556-0569)

Initial Increment Formation in Otoliths of Larval Yellowtail Rockfish

Efforts to determine the spawning times of rockfish are currently based on back calculations from estimates of daily growth increments in otoliths of rockfish YOY that have already undergone metamorphosis. The assumption is made that first increment formation occurs at parturition, the time of larval release from the female. Rockfish are internally fertilized and the eggs are incubated in the ovary. Larvae hatch in the ovary, are retained an undetermined number of days, then released into the pelagic environment.

In order to determine the stage and time of first increment formation in larval otoliths, adult female yellowtail rockfish (*Sebastes flavidus*) were held in the laboratory during the final stages of their annual reproductive cycle. Three females were anaesthetized and their larvae were sampled by means of a catheter. In addition, larvae were collected 1, 3 and 5 days after parturition. A total of 21 larvae were examined. Otoliths were examined by light and scanning electron microscopy for their core diameters, overall diameters, and the number of visible increments. Core diameters ranged 10.7 to 13.8 micra with a mean of 12.2 micra. The catheterized larvae were sampled 8 days prior to parturition. Their otoliths indicated one or two visible increments. Newly released larvae also showed one or two increments. Larvae 3 and 5 days post-release displayed three and four increments. These preliminary studies indicated that some larval otolith increments are established prior to release. Further, the first increments formed after release do not appear to be formed daily. Since many factors have been found to influence increment formation in fish larvae, additional studies appear warranted in order to determine the variability and frequency of increment formation. Such findings will greatly improve the accuracy of rockfish YOY ageing and the estimates of the time of spawning. (M. Eldridge, FTS 556-0569)

INFORMATION TECHNOLOGY SERVICES

Plans Underway to Improve SWFC Computer Access to UCSD Computing Systems

In response to a request from the staff of the Pelagic Fisheries Resources Division (PFRD) for better connectivity between personal computer (PC) users at La Jolla and various top end computing (TEC) systems at UCSD, a meeting was held to discuss available options.

The meeting was attended by representatives from all the research divisions within the La Jolla Laboratory. Interested scientific staff as well as data processing (DP) specialists were involved.

A review of several strategies for improving access to UCSD's VAX/VMS and UNIX systems was presented. These included 1) "sharing" (or "pooling") of UCSD asynchronous local area network (LAN) ports among PCs connected to the Center's 3COM LAN, 2) installation of an ethernet bridge to connect the UCSD and SWFC LANs, and 3) the use of Transmission Control Protocol/Internet Protocol (TCP/IP) to provide remote login/logoff, high speed (i.e. one million bits per second) file transfers, and email transport services between the two networks. TCP/IP is a widely used network protocol developed by the U.S. Department of Defense (DoD). It can be run on ethernet (IEEE 802.3) local area networks.

It was agreed by all meeting participants that the preferred approach for improving connectivity for the present should involve installation of an ethernet bridge. The bridge will enable a virtually unlimited number of connections for networked PCs to UCSD host systems. It also allows for the exchange of email between UCSD and SWFC TCP/IP compliant host systems (e.g. a SWFC SUN system running the UNIX operating system). It provides SWFC networked PCs with access to SWFC TCP/IP compliant hosts. Finally, it provides all the above at data transfer rates which greatly exceed those possible using asynchronous (i.e. RS-232 type) connections.

Once bridged, a SWFC SUN mini computer running UNIX could be designated by UCSD network management as a "SWFC" node on their network. This node could function as an email gateway for SWFC staff. In the extreme model, all email to SWFC staff (e.g. "Fred Nerk") might be addressed to NERK@SWFC.GOV. In this case, in order for Fred to get his email, he would first have to login to the SWFC SUN. The CPU Overhead for serving as a network email gateway is low when email traffic remains at less than 100 or so messages a day. Obviously, disk space and extra time on the part of the SUN system manager is required to support this gateway role.

Alternatively, under this option, SWFC users could continue to use existing UCSD host systems (e.g. SSURF) as their email nodes. As expected, users in that case would login to SSURF or other UCSD nodes to access their emails. (F. Ralston, FTS 893-7062)

EVENTS

Klamath Fishery Management Council Meeting Held

The Klamath Fishery Management Council met at the Southwest Fisheries Center on January 4-6, 1990, to begin its strategic planning for establishing its comprehensive long-term plan and policy. The Council, chaired by Southwest Regional Director E. C. Fullerton, is responsible for making recommendations concerning Klamath-Trinity anadromous fish harvesting to federal, state, and Indian fishery management agencies, including the Pacific Fishery Management Council. The SWFC's Planning Officer, David Mackett facilitated the first planning meeting wherein the Councils fundamental and symptomatic issues were identified and discussed and a preliminary set of goals for the Council were established. The Council will meet again on May 17-18, 1990, to continue the planning.

Klamath Fishery Management Council participants at a recent planning meeting facilitated by Regional Planning Officer, David Mackett (standing). The meeting was held at the La Jolla Laboratory, January 4-6, 1990

PUBLICATIONS

Published

Balazs, G. H. 1989. New initiatives to study sea turtles in the eastern Pacific. Mar. Turtle Newsl. 47:19-21.

Brill, R. W., and P. G. Bushnell. 1989. Cardio--A Lotus 1-2-3 based computer program for rapid calculation of cardiac output from dye or thermal dilution curves. Comput. Biol. Med. 19(5)361-366.

We have developed a menu-driven computer program (CARDIO), based on a Lotus 1-2-3 template and a series of macrocommands, that rapidly and semi-automatically calculates cardiac output from dye or thermal dilution curves. CARDIO works with any dye or thermal dilution recorder with an analog output, any analog to digital (A-to-D) conversion system, and any computer capable of running Lotus 1-2-3 version 2. No prior experience with Lotus 1-2-3 is needed to operate CARDIO, but experienced users can take full advantage of Lotus 1-2-3's graphics, data manipulation, and data retrieval capabilities.

Chess, J.R. 1989. *Aciconula acanthosoma*, new species, a caprellid amphipod from southern California, with notes on its ecology. J. Crust. Biol. 9(4):662-665.

A caprellid amphipod, *Aciconula acanthosoma*, new species, is decribed from nearshore waters of Santa Catalina Island, California. Previously the genus, *Aciconula* was monotypic, known only from the western Pacific species *A. miranda*. The new species was common and persistent during 15 years of sampling, and was found on 12 types of substrata and in the gut contents of eight species of fishes. It is distinguished from *A. miranda* primarily by the spination of the head and pereionites.

Crossland, J., S. Pooley, K. Kawamoto, P. W. Philipson, and M. J. Riepen. 1989. The markets for chilled Pacific Island fish in Japan, Hawaii, Australia and New Zealand, pp. 251-292. *In*: P. W. Philipson (ed.), The marketing of marine products from the South Pacific. Institute of Pacific Studies of the University of the South Pacific, Suva, Fiji, Chapter 14.

Hightower, Joseph E. and William H. Lenarz. 1989. Optimal harvesting policies for the widow rockfish fishery. Am. Fish. Soc. Symp. 6:83-91.

We developed optimal harvesting policies for the widow rockfish *Sebastes entomelas* fishery using a microcomputer-based age- structured model. We compared traditional constant effort policies to more complex escapement policies (control of spawning stock size) using three criteria: the difficulty of estimating policy parameters, the average harvest obtained, and the variability in harvest. Substantial computational effort was required to obtain optimal estimates for the two-parameter escapement policies,

and a single run usually required 24 h or more to complete on a microcomputer. Conservative escapement policies were similar in form and in performance to constant effort policies. Mean harvest under the least-conservative escapement policy was only about 2% greater than mean harvest under a constant effort policy, yet variability in harvest increased by 49%. For stocks where density dependence is not strong, we suggest that only minor improvement will be gained through the use of two-parameter escapement policies.

Hightower, Joseph E. and William H. Lenarz. 1989. Using GENMOD to develop harvesting policies for multiaged fish stocks. Am. Fish. Soc. Symp. 6:209-210.

Program GENMOD is a microcomputer-based simulation program that applies an age-structured population model to problems of optimal harvesting policy. It can be used to explore alternative harvesting policies and determine the policy that best satisfies conflicting objectives of fishery management. This public-domain program is written for IBM PC and PC-compatible systems.

Humphreys, R. L., Jr., R. B. Moffitt, and M. P. Seki. 1989. First record of the bigeye sand tiger shark *Odontaspis noronhai* from the Pacific Ocean. JPN J. Ichthyol. 36(3):357-362.

MacCall, A. D. 1990. Dynamic geography of marine fish populations. Washington Sea Grant Program, Seattle, 153 pp.

Ralston, S. 1989. Effect of seasonal recruitment on bias of the Beverton-Holt length-based mortality estimator. Amer. Fish. Soc. Symp. 6:190-197.

The Beverton and Holt mortality estimator is a length-based formulation often applied to tropical fish stocks. Although constant uniform recruitment of fish to the exploitable phase is an important condition of its derivation, the robustness of the estimator when this assumption is violated has never been studied. This is important because evidence from the literature shows that in the tropics (i.e., Hawaii) both recruitment and spawning are distinctly seasonal events. Thus, to study properties of the estimator when recruitment is variable, a simple model with seasonal reproduction was developed and analyzed. I show that if age is measured discretely in units equal to the period of the recruitment function, typically 1 year, the age distribution is stationary. The model is extended to length distributions and used as a basis for Monte Carlo simulation of the estimator. Results show that, seasonally, the time of sampling has a major effect on the relative bias of mortality estimates. Bias is negative during periods of increasing recruitment and vice versa, whereas no bias exists at times of maximal and minimal recruitment. Likewise, as the underlying mortality rate increases, bias becomes more severe. When multiple length-frequency samples are drawn and the data and estimates are aggregated, relatively little bias is evident. These results suggest that, when the estimator is used in situations in which recruitment is periodic, it may be better to obtain many small samples than a single large sample, unless some prior information exists concerning the form of the recruitment function.

Approved by Science and Research Director, SWR

Bowers, Michael J. Histological assessment of the reproductive cycle of female yellowtail rockfish, *Sebastes flavidus* (Family Scorpaenidae). For consideration for publication in Fishery Bulletin, U.S.

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Kusher, David I., Susan E. Smith and Gregor M. Cailliet. Validated age and growth of the leopard shark, *Triakis semifasciata*, with comments on reproduction. For consideration for publication in the Journal of Fish Biology.

Polovina, J. J. A global perspective on artificial reefs and fish aggregating devices. FAO IPFC Workshop.

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Squires, Dale and James Kirkley. The organization of production in revenue-maximizing multiproduct industries. For consideration for publication in the International Journal of Industrial Organization.

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Moser, H. Geoffrey and William Watson. 1990. Distribution and abundance of early life history stages of the California halibut, *Paralichthys californicus*, and comparison with the fantail sole, *Xystreurys liolepis*. SWFC Admin. Rep., La Jolla, LJ-90-04, 42 p.

Perrin, Christina H., Bruce E. Wahlen and Elizabeth F. Edwards. 1990. Simulation procedures for investigating the effects of various sample sizes on estimates of incidental dolphin mortality. SWFC Admin. Rep., La Jolla, LJ-90-05, 59 p.

Polovina, J. J. 1990. Status of lobster in the northwestern Hawaiian Islands, 1989. SWFC Admin. Rep., Honolulu, H-90-2, 11 p.

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